
CATALOGUE No. 7



**Air Compressing
Machinery
AND
IMPROVED ROCK DRILLS**



BUILDERS OF

**Risdon Water Wheels "Pelton Type"
Improved Bryan Roller Mills
Evans Hydraulic Elevators and
Hydraulic Mining Machinery
Ore Feeders, Rock Breakers
Mining, Pumping and Hoisting Plants
Knight's Water Wheels**



PUBLISHED BY

The Risdon Iron Works

SAN FRANCISCO, CAL.

1897

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Risdon Iron and Locomotive Works

SAN FRANCISCO, CAL.

MANUFACTURERS OF IMPROVED

MINING MACHINERY

Adapted to Mining Operations of any Magnitude, and the Systematic Treatment of Gold, Silver, Copper, Lead and other ores, by any of the Popular Methods

Direct Acting Hoisting Engines	Water Jacket Smelting Furnaces
Direct Acting Pumping Engines	Lead-Silver Smelting Works
Geared Hoisting Engines	Reverberatory Roasting Furnaces
Hydraulic Pumping Plants	Mechanical Roasting Furnaces
Friction Hoisting Engines	Revolving and Kiln Ore Dryers
Portable Hoisting Engines	Gold Stamp Mills
Rock Drilling Machinery	Copper Smelting Works
Geared Pumping Engines	Feed-Water Heaters
Water Wheel Hoists	Concentrating Mills
Hydraulic Hoists	Silver Stamp Mills
Steam Pumps	Bryan Roller Mills
Plunger Pumps	Chlorination Works
Bucket Pumps	Steam Engines
Working Bobs	Steam Boilers
Balance Bobs	Steam Feed Pumps
Air Compressors	Water Wheels
Ventilating Machinery	Power Transmission
Tramway Machinery	Common Sense Whims
Hoskins Giants	Johnston Concentrators
Evans' Hyd. Gravel Elevators	Risdon Concentrators

Steam Vessels and Marine Machinery

Including High Pressure, Condensing, Compound, Tripple and Quadruple Expansion Engines; Steam Boilers of the Latest Designs, and other Machinery Equipments for Steam Vessels Designed and Built for all Kinds of Ocean, Harbor and River Service.

GENERAL MACHINERY

For the Application of Steam Power, Hydraulics, Pneumatics, Electricity and for Manufacturing Purposes

EXCLUSIVE AGENTS AND MANUFACTURERS

For the Pacific Coast of Heine's Safety Boilers, Steel Whims, Bryan Mills
Johnston Concentrators, Hoskin's Giants,
Smith-Vaile Pumps

Hydraulic Riveted Sheet Steel and Iron Pipe a Specialty

DONE IN SAN FRAN-
CISCO AT PRINTING
SHOP OF THE E. D.
TAYLOR COMPANY,
IN THE MONTH OF
JANUARY AND YEAR
EIGHTEEN HUN-
DRED AND NINETY-
EIGHT.

PREFACE.

The use and application of compressed air dates back more than a century. but it has been only within the last few years that its greatest value as a power transmitter has been fully recognized.

Engineers in general have looked with indifference upon the use of compressed air as a means of power transmission, considering the method one of very low efficiency. This was due largely to the fact that no accurate and reliable data were available from which to form conclusions.

The large Compressed Air Power Plants, installed at Paris, France, and Birmingham, England, delivering and distributing power, miles from the central stations, have clearly demonstrated the economical value of the system, and have furnished a large amount of data, obtained from practical working tests, affording the most trustworthy results as to loss in pressure due to resistance in pipes, and the efficiency of the compressors and motors employed.

It is safe to say, that when power is transmitted short distances, from one to two miles, it can be accomplished by compressed air cheaper than by electricity, both as to first cost and maintenance.

For the underground work in mines, such as pumping, hoisting and drilling, compressed air is superior to all other know methods, and will hold the field against all competitors. The reasons for this are so obvious that they need not be enumerated.

Our Catalogue No. 7, on Air Compressors and Drills, we submit to the mining public, and would state that our experience in machinery of this kind is of thirty-five years building strictly first-class compressors.

Our Compound Air Cylinders are, without doubt, the most efficient two stage machine ever built.

We particularly call attention to our Ring Inlet Valve which, after ten years use, perfected up to date, we can guarantee a volumetric efficiency greater than any other.

We are prepared to submit figures on transmission of Pneumatic Power any distance.

INDEX

	PAGE
Air Receivers.....	62
Air required for Rock Drills.....	63
Belt Power Compressors.....	32, 36, 40
Blowing Engines.....	76, 77, 78, 79
Bryan Mills.....	95
Corliss Air Compressors.....	9, 10
Cross Compound Corliss Compressors.....	16
Columns for Drills.....	45
Capacity of Compressors.....	64
Capacity of Air Cylinders.....	65
Descriptive Air Cylinders.....	6
Dimensions Corliss Compressors.....	14
Dimensions Cross Compound Compressors.....	18
Drills.....	42, 43 to 53
Drill Steel.....	53
Directions for Operating Drills.....	54
Dredging.....	94
Efficiency of Compound Air.....	83 to 92
Geared Compressors.....	36
Gold Dredging.....	94
Horse Power to Compress Air.....	66, 67
Hoisting by Compressed Air.....	73, 74
Introduction.....	5
Loss by Friction of Air.....	68
Myers' Cut-off Compressors.....	26
Milling Catalogue.....	96
Operating Drills.....	54
Pumping by Compressed Air.....	70, 71, 72
Parts for Drills.....	60, 61
Pipes, Sizes.....	69
Receivers.....	62
Risdon Ring Inlet Air Cylinders.....	6
Risdon Regulators.....	8
Reheating.....	75
Sizes Half Duplex and Duplex.....	12
Straight Line Compressors.....	28
Steel for Drills.....	53
Specifications for Drill Plants.....	56 to 59
Two Stage Compressors.....	20 to 25
Table of Sizes Pipes.....	69
Unloading Device.....	8
Useful Compound Air Formula.....	80, 81
Valve Gear Corliss Compressors.....	11
Water Power Compressors.....	30, 33, 34
Water Wheels.....	93

INTRODUCTION.

This company has had an experience of over 35 years in the manufacture of air compressors, during which time we have used and tested the different devices for the compression of air, and the several types finally selected and now manufactured by us may be accepted with full confidence that they embody every essential point which makes machinery of this kind good, economical and durable, not for a time only, but permanently so.

A marked peculiarity of air compressors and other machinery built by this company is simplicity and absence of complication. Such machinery can be put in the hands of ordinary engineers with every assurance that good service and economy will be maintained. The importance of this will be seen when it is remembered that compressed air can only be used with economy when it is obtained at the least cost. Other machines are soon at a disadvantage because they require close watching and constant adjustment and refitting to insure tightness of the working parts without which economy is impossible.

It is a fundamental fact in business, and especially in the air compressor business, that a product of a high class, the best in its line, does and always will command a higher price. The difference in price between the best compressor and one not so good, divided by the number of days in the fifteen or twenty years of use, amounts to but a few cents a day, and this may be regarded as cheap insurance against breakdowns and incidental delays. This difference is besides made up over and over again every day in the greater economy of fuel and maintenance.

It is plain by comparison that although Risdon Ring Inlet Air Compressors are simple in design, they are of such strength, and in material and workmanship are of such a high standard, that under equal conditions they cost more to build than to build any other air compressor. The superior quality so gained, however, returns its extra cost many times over in the lifetime of the machine.

When asking for quotations on air compressors, state the volume required per minute, mentioning whether this is *free* air or compressed air; state the pressure required and whether a steam-driven or belt compressor is wanted. If the former, state the steam pressure carried. If the above questions cannot be answered, give full details of the work to be done and we will give you our best advice on the subject.

Remember our Inlet Valves insure a greater volumetric efficiency than any other compressor of equal area.

Our Ring Inlet Valves and Regulators are fully covered by U. S. Patents.

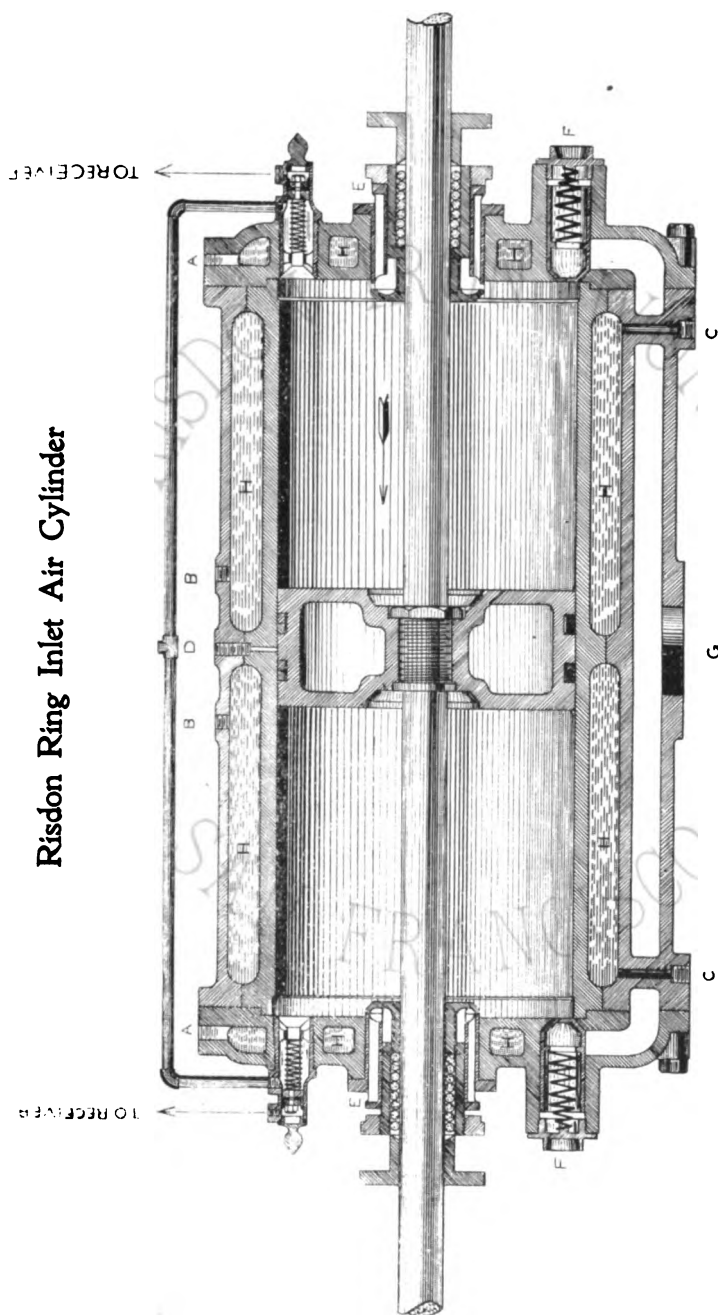
Description of Risdon Ring Inlet Air Cylinders

The Air Inlet Valves E, located in each head, are carried on piston and tail rod, giving positive action with the slightest movement of the machine. The cylinders are completely jacketed on walls and heads.

The walls have an independent stream of water from centre to each head. The volumetric efficiency of our Air Cylinders exceeds that of any other make.

Our regulators govern all kinds of motive power.

Risdon Ring Inlet Air Cylinder



DETAILS OF AIR CYLINDER

- | | |
|------------------------------------|--------------------------|
| A - CIRCULATING WATER INLET | E - AIR INLET VALVES |
| B - CIRCULATING WATER OUTLET | F - AIR DISCHARGE VALVES |
| C - WATER JACKET DRAIN PIPE | G - AIR DISCHARGE |
| D - OIL HOLE FOR AUTOMATIC OIL CUP | H - WATER JACKET |
| | I - RELIEF VALVES |

Risdon Compressor Regulator or Unloading Device

This regulator is for the purpose of taking load off engine when the pressure required is reached, and consists of the Relief Valves I attached to either end of the cylinder, and are operated by a differential valve (See page 7) with pressure from receiver. When the pressure reaches the desired point the Valves I are opened, allowing the air to circulate from one end of the piston to the other; at the same time the air acts on the governor of the engine, cutting off the steam at such a point that the engine will just turn over; as the pressure falls, the valves close and the engine takes up load as before.

On water wheels the regulator shuts off the water gate and slowly closes off the water from water wheels, opening again when more pressure is required. On Compressors operated by tight and loose pulleys, the regulator operates the bell shifter.

Our regulators are patented, and only used on our make of Compressors.

DESCRIPTION OF RISDON CORLISS AIR COMPRESSORS

High Pressure, Cross Compound, Tandem Compound or Triple Expansion

THE FRAMES are of the Girder type, made very strong, and provided with a center support, with feet spread well apart, insuring great stiffness and strength.

THE CYLINDERS are made of the best selected close-grained charcoal iron, mixed with selected scrap, and are of proper strength and thickness for operating with 125 pounds steam pressure after having been reboresd once. The material is such that the wearing surfaces become polished after a few days' use, after which, with reasonably dry steam, the wear amounts to so little, that the piston remains tight for an indefinite length of time. The cylinders are neatly lagged, and the space between lagging and cylinder packed with non-conducting material, to prevent condensation as much as possible. The steam passages are short and direct, reducing clearance to the least possible amount. The cylinder is supported upon two pedestals with extended base, with ample bearing surface on the foundation. The vacuum dash pots are secured firmly to the sides of these pedestals. Strong lugs are provided for connecting the air cylinders tandem by means of suitable tie rods.

THE STEAM PISTONS are what is known as the double ring type. There are two bull rings and a self-expanding steam ring, re-enforced by elliptic springs. The piston is so constructed that by taking off the follower the bull rings and steam rings can be taken off without removing the piston. This is a great convenience, as it is sometimes necessary to examine the steam ring. It is a very durable construction, for the reason that the bull rings and steam ring can at any time be replaced at small expense, and the piston then is practically as good as new.

THE SHAFTS are of the best wrought iron, of extra large diameter, and turned, keyseated and nicely finished. The bearings are polished to reduce friction to the lowest point.

THE MAIN BEARINGS.—The main pillow blocks are provided with removable shell boxes, with quarter boxes lined with genuine Babbit metal, hammered and strapped to fit the shaft. Approved means for taking up all lost motion is provided. The bearings are of ample length, and large oil boxes are provided, with means for ready access to the shaft. The bearings run smoothly, cool and quiet under the heaviest loads.

THE CRANKS are of the best selected charcoal iron, and of ample strength and proportion for the work to be done; they are of the disk pattern, and the weight of the connecting rod and crank pin are counterbalanced on the opposite side, thus reducing end motion and vibration to the minimum. They are pressed on the shaft by hydraulic pressure, and securely keyed. The faces are planed and polished.

THE FLY-WHEELS are extra heavy, of square rim pattern, the faces and edges being turned practically true. The arms are of ample strength and well proportioned. The larger sizes are made in segments, accurately planed and fitted together with turned bolts in reamed holes. Rims of wheels are provided with starting bar holes.

THE CONNECTING RODS are of forged steel, with solid ends and key adjustment. The cross-head end is fitted with phosphor-bronze box, and the crank end with a composition box, bored and scraped to fit the pin.

THE CROSS-HEADS are provided with adjustable shoes for taking up all wear. The guides are bored and scraped to a perfect surface. The shoes are lined with Babbit metal, hammered and scraped to a perfect bearing in the slides. The cross-head pins are of forged steel, turned, polished and fitted to the cross-head by a double taper. They are easily removed and securely held in place with a nut or cap.

THE VALVE GEAR is of our latest improved Corliss liberating type, fitted with vacuum dash pots. The connecting rods and pins are all of the best forged steel, and are fitted with phosphor-bronze bearings, adjustable for wear; provision for thorough lubrication is made, and the entire gear motion works smoothly and quietly. The catch blocks are of hardened steel.

THE VALVES are slotted at one end to receive the Tee shaft heads of the valve stems, and are so constructed that any valve can be taken out without disturbing the valve stems or changing the adjustment of the valve gear. It is only a few minutes' work to take all the valves out of the Corliss Engine and put them back again, and can be done by any engineer.

THE GOVERNOR is of the fly ball type, provided with an automatic safety stop, and furnished with approved means for adjusting the speed by hand, within the widest possible limits, without altering the throttle valve.

THE THROTTLE VALVES are furnished with flanges and large hand wheels, nicely turned and finished. A brass drain pipe leading to the exhaust is provided.

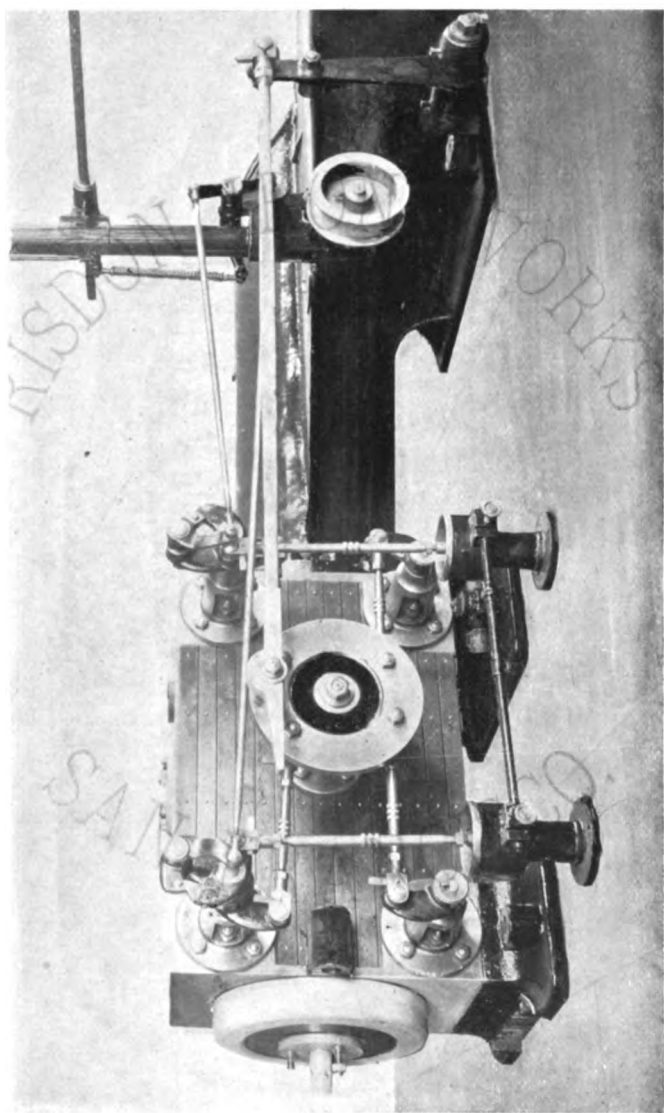
All usual oil cups and sight feed lubricators for air and steam cylinders are provided, of extra large size. A hand pump for steam cylinders and centrifugal oilers for cranks are also supplied, the lubrication being automatic throughout.

Indicator connections are furnished for each steam cylinder, with valve at each end.

A full set of wrenches for adjusting all bolts and nuts, with necessary eyebolts, is supplied.

All necessary holding down bolts with anchor plates, together with foundation plans, are furnished.





Special Corliss Valve Gear used on our Corliss Engine

Cutting off from 0 to 7-10 of stroke.

RISDON HIGH PRESSURE DUPLEX AND HALF DUPLEX CORLISS AIR COMPRESSORS WITH RISDON RING INLET AIR CYLINDERS

Air Pressure 100 lbs.

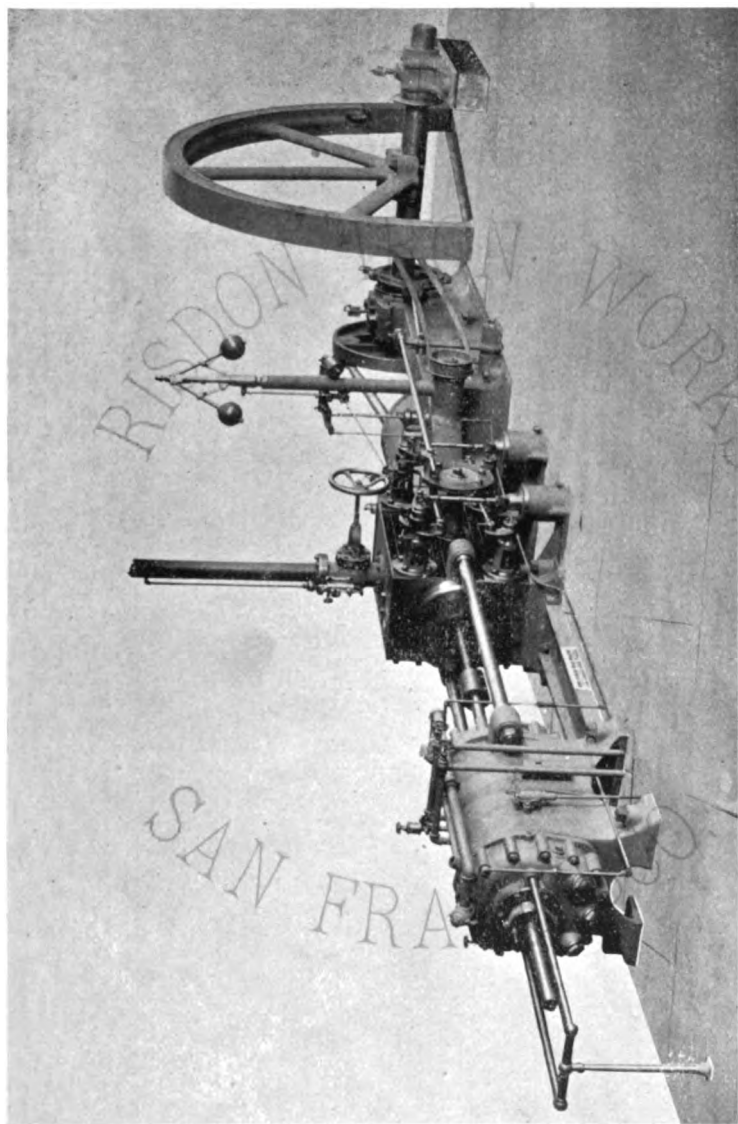
Size No.	Sizes of Cylinders			Revolutions per Minute	Piston Speed in Feet per Minute	Capacity Duplex		Indicated
	Diameter		Stroke Inches			Cubic Feet Free Air		Horse Power
	Steam Inches	Air Inches				Per Min.	Per Rev.	Duplex
1	10½	10	30	90	450	547	6.080	110
2	12	12	30	87	485	684	7.865	138
3	14	14	36	85	510	1080	12.71	218
4	14	14	42	82	574	1216	14.83	244
5	16	16	36	82	492	1359	16.58	274
6	16	16	42	78	546	1509	19.34	304
7	18	18	36	80	480	1674	20.92	336
8	18	18	42	78	546	2061	25.76	382
9	18	18	48	75	590	1904	24.41	422
10	20	20	42	75	525	2093	27.90	454
11	20	20	48	72	576	2473	34.35	498
12	22	22	42	75	525	2718	36.24	546
13	22	22	48	72	579	2982	41.41	601
14	24	24	42	75	525	3211	42.82	646
15	24	24	48	70	560	3425	48.93	690
16	26	26	48	70	560	4033	57.62	813
17	38	28	48	68	544	4559	67.05	919
18	30	30	48	65	520	5015	77.16	1011
19	30	30	60	62	620	5980	96.45	1205
20	32	32	48	65	520	5718	87.97	1153
21	32	32	60	62	620	6817	109.96	1373

Air Pressure 80 lbs.

2	10½	12	30	90	450	708	7.865	97
2	12	14	30	78	435	921	10.59	163
23	14	16	36	85	510	1409	16.58	249
24	15	16	42	82	574	1596	19.34	281
26	16	18	36	82	492	1716	20.92	303
27	16	18	42	78	546	1904	24.41	237
28	18	20	36	80	480	2061	25.76	365
29	18	20	42	78	546	2344	30.05	415
30	18	20	48	75	590	2576	34.35	456
31	20	22	42	75	525	2718	36.24	480
32	20	22	48	72	576	2982	41.41	528
33	22	24	42	75	525	3211	42.82	569
34	22	24	48	72	576	3523	48.93	625
35	24	26	42	75	525	3782	50.42	670
36	24	26	48	70	560	4033	57.62	715
37	26	28	48	70	560	4693	67.05	830
38	28	30	48	68	544	5247	77.16	927
39	30	32	48	65	520	5718	87.97	1013
40	30	32	60	62	620	6817	109.96	1207
41	32	34	48	65	520	6427	98.88	1138
42	32	34	60	62	620	7662	123.58	1357

These Compressors are all made with Risdon Ring Inlet Air Cylinders. Air cylinders and heads are water jacketed. Steam cylinders neatly lagged.

These Compressors are furnished with governor, provided with automatic safety stop; and with pressure regulator and unloading device on air cylinders. Sight feed lubricators on all air cylinders, and all necessary oil cups. Foundation bolts and anchor plates. Foundation plans furnished with each Compressor



Risdon Half-Duplex Corliss Air Compressor.

TABLE SHOWING SOME OF THE MOST IMPORTANT

Dimensions of Risdon High Pressure Corliss Air Compressors

WITH

Risdon Ring Inlet Air Cylinders

Air Pressure 100 lbs.

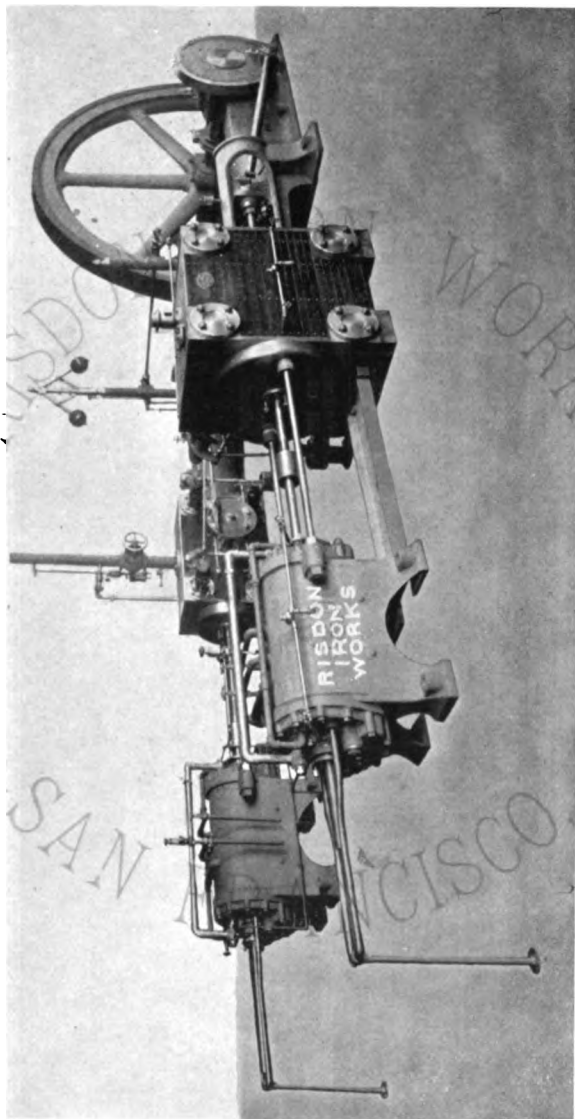
Size Number.	Size of Pipes in Inches.				F. W. & Shaft in Inches.				Approximate Weight.			
	Main Steam Pipes.	Each Steam Inlet.	Exhaust Outlet.	Each Air Outlet.	Circulating Water.	Diameter of Flywheel.	Diameter Shaft in Bearings.	Diam. Shaft between Bearings.	Floor Space in Feet and Inches.	Flywheel.	Half Duplex.	Duplex.
1	5	3	5	3	1	9	6	7	31 x 10	10000	27120	38090
2	5	3½	5	3	1	10	6	7	31 x 10	10400	29320	41290
3	6	4	6	3½	1	10	7	9	34 x 12	13500	36440	51500
4	6	4	6	3½	1	12	7	9	38 x 12	15000	40390	57140
5	6	4½	6	4	1	14	8	10	36 x 12	15000	46930	66400
6	6	4½	6	4	1	16	8	10	4 x 12	17500	51220	71880
7	7	5	7	5	1¼	16	9	11	38 x 13	20000	54000	75310
8	7	5	7	5	1¼	16	9	11	40 x 13	22000	57850	79890
9	7	5	7	5	1¼	18	9	11	46 x 13	25000	67850	96240
10	9	6	8	5	1¼	16	1	12	41 x 13	25000	69500	94650
11	9	6	8	5	1¼	18	10	12	47 x 13	30000	79300	108100
12	9	6	8	6	1¼	18	11	13	42 x 14	30000	80750	111850
13	9	6	8	6	1¼	18	11	13	47 x 14	36000	88550	119300
14	10	7	9	6	1½	20	12	14	43 x 14	56000	97200	131800
15	10	7	9	6	1½	20	12	14	49 x 15	38000	103700	142150
16	12	8	12	7	1½	20	13	15	49 x 15	45000	117950	161200
17	12	8	12	7	1½	20	14	16	49 x 16	50000	135800	184100
18	12	8	12	8	1½	22	15	17	41 x 16	55000	148570	203540
19	12	8	12	8	1½	21	15	17	59 x 17	60000	169150	240900
20	13	9	13	8	1½	22	16	18	41 x 19	60000	163400	236800
21	13	9	13	8	1½	24	16	18	60 x 19	80000	190000	280000

Air Pressure 80 lbs.

22	5	3	5	3	1	9	6	7	31 x 10	10000	27330	38500
23	5	3½	5	3	1	10	6	7	31 x 10	10400	29520	41690
24	6	4	6	4	1	10	7	9	34 x 12	13500	37140	52900
25	6	4	6	4	1	12	7	9	38 x 12	15000	41040	58440
26	6	4½	9	5	1¼	14	8	10	36 x 12	15000	48130	68800
27	6	4½	6	5	1¼	16	8	10	40 x 12	17500	52470	74380
28	7	5	7	5	1¼	16	9	11	38 x 13	20000	54200	75710
29	7	5	7	5	1¼	16	9	11	40 x 13	22000	58940	82090
30	7	5	7	5	1¼	08	9	11	46 x 13	25000	68950	98440
31	9	6	8	6	1¼	06	00	12	41 x 13	25000	90900	95450
32	9	6	8	6	1¼	08	00	12	47 x 13	30000	79800	109100
33	9	6	8	6	1½	08	00	13	42 x 14	30000	82250	114850
34	9	6	8	6	1½	08	00	13	47 x 14	36000	90750	123700
35	10	7	9	7	1½	20	02	14	43 x 14	36000	99200	135800
36	10	7	9	7	1½	20	02	14	49 x 15	38000	105700	146150
37	12	8	12	7	1½	20	03	15	49 x 15	45000	118450	162200
38	12	8	12	8	1¼	20	04	16	49 x 16	50000	136800	187100
39	12	8	12	8	1½	22	05	17	41 x 16	55000	149470	205340
40	12	8	12	8	1½	24	05	17	59 x 17	50000	169650	241900
41	13	9	13	8	1½	22	06	18	41 x 19	60000	164750	239500
42	13	9	13	8	1½	24	06	18	60 x 19	70000	191000	282000

Duplex illustrated page 13.

Half Duplex illustrated page 15



RISDON DUPLEX RING INLET COMPRESSOR

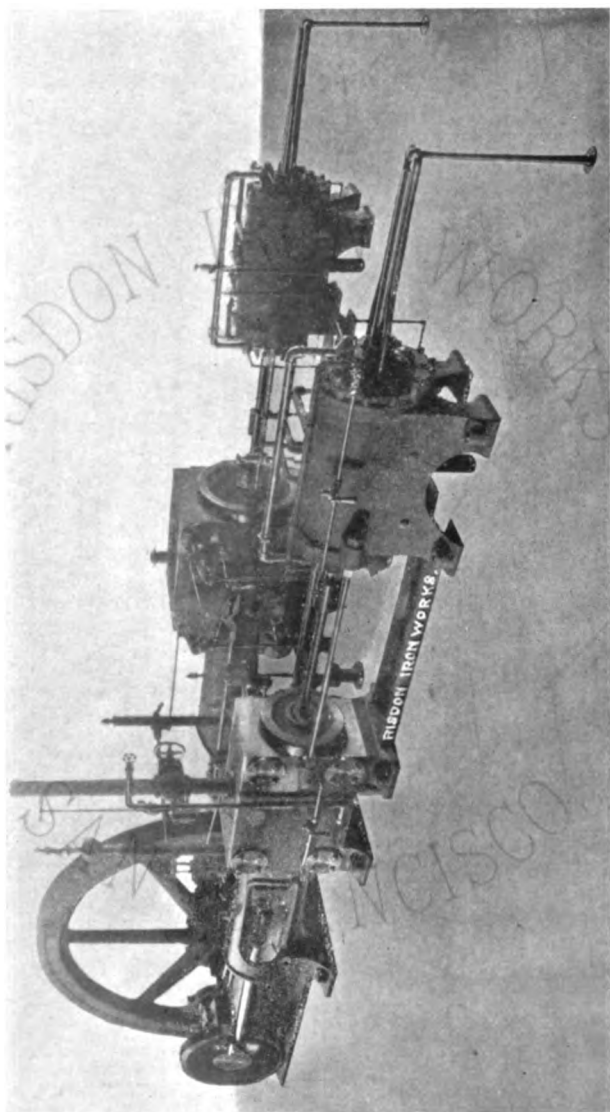
With Cross Compound Corliss Engine.

Risdon Cross Compound Corliss Air Compressors

With Cross Compound Steam Cylinders and Risdon Ring Inlet
Air Cylinders

Air Pressure 100 lbs.

Size Number.	Size of Cylinders in Inches.				Length of Stroke.	Revolutions Per Minute.	Piston Speed in Feet Per Minute.	Capacity Duplex.		Horse Power.	
	Diameters.			Cubic Feet Free Air.				I. H. P. of Comp.	Boiler H. P. Com- denser Attached.		
	Steam.	Air.									
	High Pressure.	Low Pressure.					Per Minute.	Per Revolution.			
43	10½	18	10¾	30	90	450	547	6.08	110	65	
44	12	22	12	30	87	435	684	7.86	138	85	
45	14	26	14	36	85	510	1080	12.71	218	130	
46	16	30	16	36	82	492	1359	16.58	274	165	
47	14	26	14	42	82	574	1216	14.83	244	145	
48	16	30	16	42	78	546	1509	19.34	304	180	
49	18	34	18	36	80	480	1674	20.92	336	200	
50	18	34	18	42	78	546	1904	24.41	382	230	
51	20	36	20	36	80	480	2061	25.76	414	250	
52	20	36	20	42	75	525	2254	30.05	454	270	
53	18	34	18	48	75	590	2093	27.90	422	250	
54	20	36	20	48	72	576	2473	34.25	498	300	
55	22	40	22	42	75	525	2718	36.24	546	330	
56	22	40	22	48	72	576	2982	41.41	600	360	
57	24	44	24	42	75	525	3211	42.82	546	390	
58	24	44	24	48	70	560	3425	48.93	690	415	
59	26	48	26	48	70	560	4033	57.62	812	485	
60	28	52	28	48	68	544	4559	67.05	920	550	
61	30	56	30	48	65	520	5015	77.16	1011	600	
62	30	56	30	60	62	620	5980	90.45	1205	725	

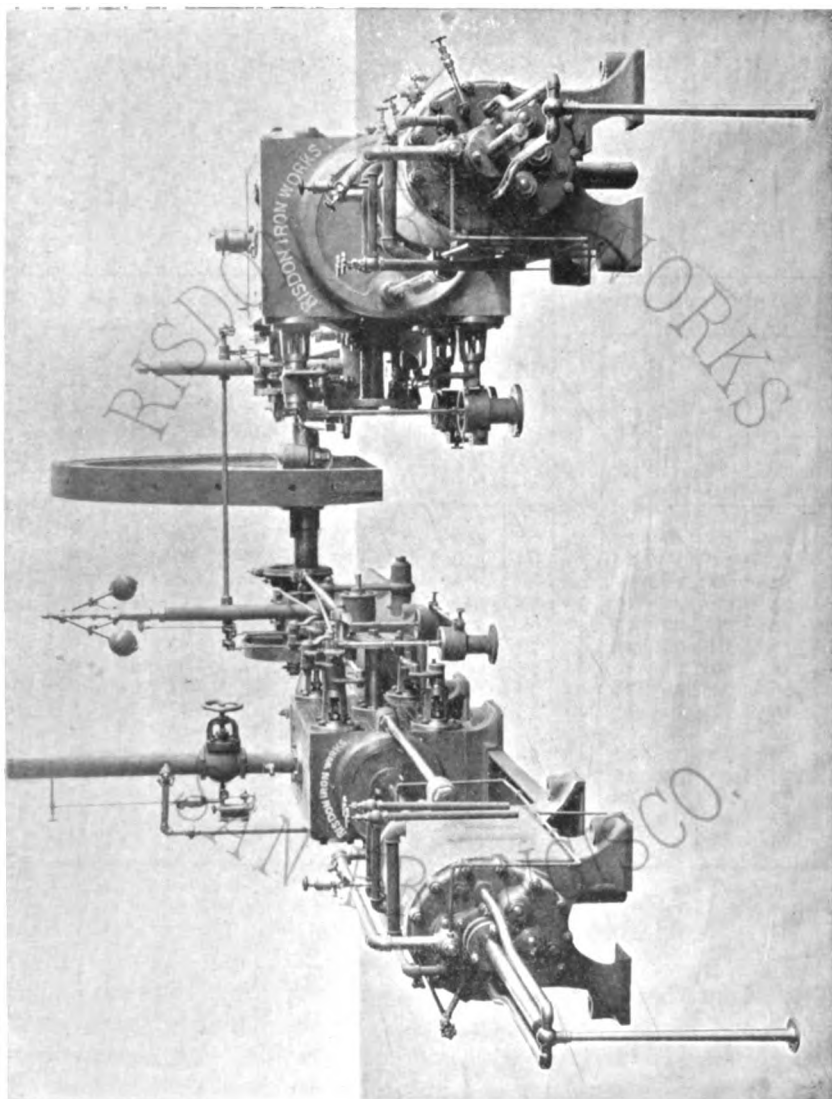


Risdon Duplex Air Compressor with Cross Compound Corliss Engine

Dimensions of Risdon Cross Compound Corliss Engines with Risdon Ring Inlet Air Compressing Cylinders.

Air Pressure 100 Pounds.

Size Number.	Sizes of Pipes, Inches.				Flywheel and Shaft.			Floor Space, Feet.	APPROXIMATE WEIGHTS.			
	Steam Pipes.	Exhaust Outlet.	Each Air Outlet.	Circulating Water.	Diameter.				Complete Compressor.			
					Flywheel, ft.	Shaft, In.			Flywheel.	With Surface Condensor.	With Jet Condensor.	Without Condensor.
						In Bearings	Between Bearings					
43	3	5	3	1	9	6	7	34 x 14	10000	48000	47000	43000
44	3½	5	3	1	10	6	7	34 x 14	10000	52000	50000	46000
45	4	6	3½	1	10	7	9	38 x 14	16500	69000	68000	62000
46	4½	6	4	1	14	8	10	40 x 15	21000	91000	89000	82000
47	4	6	3½	1	12	7	9	42 x 14	18500	76000	75000	69000
48	4½	6	4	1	16	8	10	44 x 15	23000	97000	94000	88000
49	5	7	5	1¼	16	9	11	42 x 16	29000	106000	104000	97000
50	5	7	5	1¼	16	9	11	44 x 16	31500	115000	110000	103000
51	6	8	5	1¼	16	10	12	42 x 16	31500	120000	111000	108000
52	6	8	5	1¼	16	10	12	45 x 16	32500	129000	124000	116000
53	5	7	5	1¼	18	19	11	50 x 16	32500	129000	123000	116000
54	6	8	5	1¼	18	10	12	51 x 16	33000	140000	134000	126000
55	6	8	6	1¼	18	11	13	46 x 18	40000	151000	146000	138000
56	6	8	6	1¼	18	11	13	51 x 18	44000	160000	156000	145000
57	7	9	6	1½	20	12	14	48 x 19	46000	178000	171000	159000
58	7	9	6	1½	20	12	14	53 x 19	50000	194000	184000	173000
59	8	12	7	1½	20	13	15	53 x 21	60000	225000	218000	202000
60	8	12	7	1½	20	14	16	53 x 21	65000	264000	257000	237000
61	8	12	8	1½	22	15	17	55 x 22	75000	295000	287000	267000
62	8	12	8	1½	24	15	17	64 x 22	90000	348000	336000	314000



Risdon Duplex Air Compressor with Cross Compound Corliss Engine

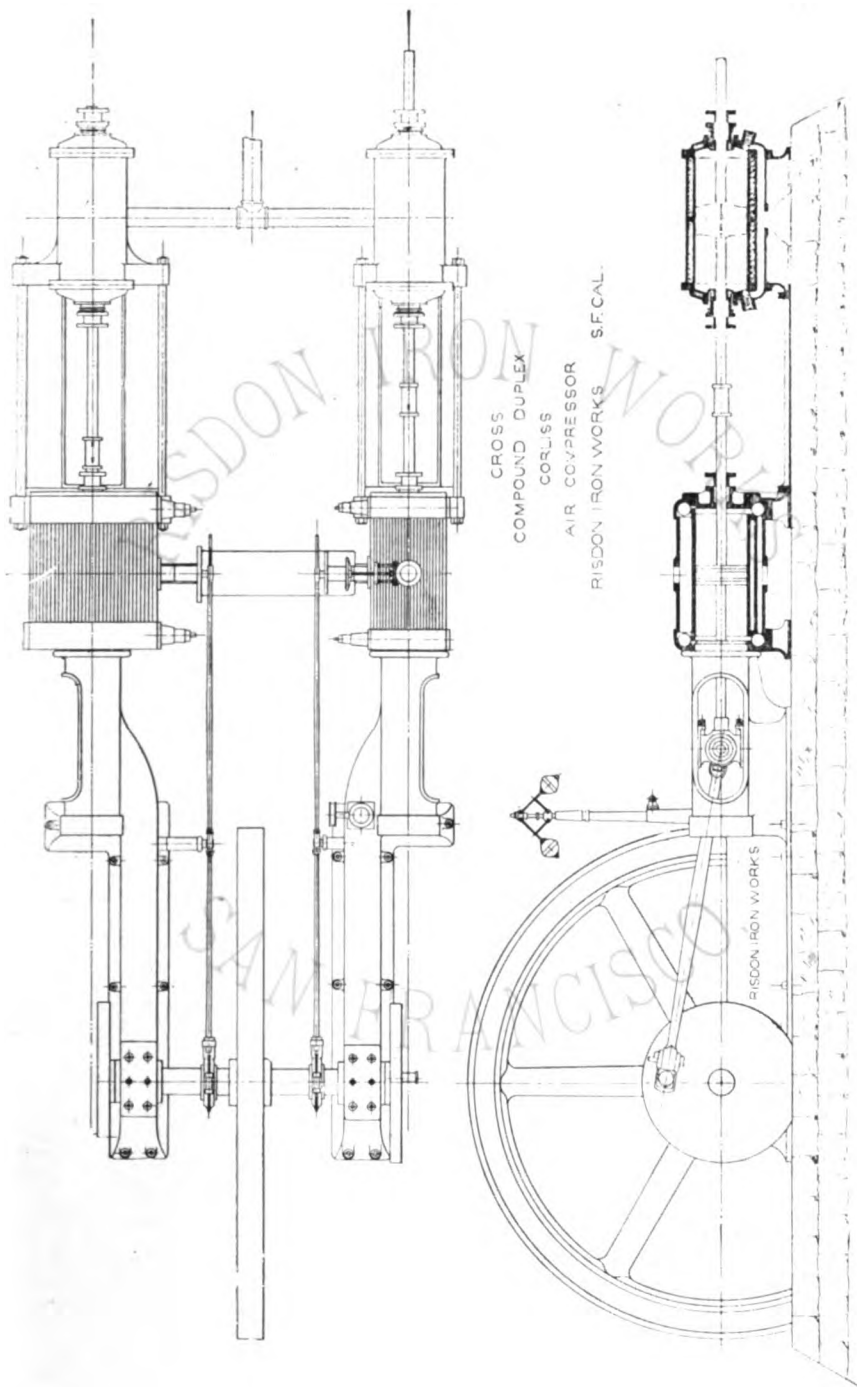
Risdon Cross Compound Corliss

With Cross Compound (2 stage) Air Cylinder.

Air Pressure 100 lbs.

Size Number.	Size of Cylinders in Inches. Diameters.						Revolutions per Minute.	Piston Speed in Feet per Minute.	Capacity. Cubic Feet Free Air.		Horse Power.		Intercooler.	
	Steam.		Air.		Per Minute.	Per Revolution.			I. H. P. of Comp.	Boiler H. P. Con- denser Attached.	Diameter in Inches.	Length in Feet.		
	High Pressure.	Low Pressure.	Low Pressure.	High Pressure.									Stroke.	
63	10½	18	16	10	30	90	450	571	6.35	97	60	36	8	
64	12	22	18	11	36	85	510	889	10.46	152	90	36	8	
65	12	22	18	11	42	82	574	1000	12.20	170	100	36	8	
66	14	26	22	13	36	85	510	1325	15.60	225	135	42	9½	
67	14	26	22	13	42	82	574	1489	18.12	253	150	42	9½	
68	16	30	24	14	42	78	546	1670	21.41	284	170	42	9½	
69	16	30	24	14	48	75	600	1834	24.46	312	185	42	9½	
70	16	30	26	15	42	78	546	1980	25.21	337	200	42	9½	
71	16	30	26	15	48	75	600	2160	28.81	367	220	42	9½	
72	18	34	28	17	48	75	600	2513	33.52	427	250	48	11	
73	20	36	30	18	48	72	576	2777	38.58	471	280	48	11	
74	22	40	32	19	48	72	576	3160	43.98	540	325	48	11	
75	22	40	34	20	48	72	576	3558	49.44	604	360	60	13½	
76	22	40	34	20	60	65	650	4016	61.79	685	415	60	13½	
77	24	44	36	22	48	70	560	3904	55.78	664	400	60	13½	

These Compressors are all made with Risdon Ring Inlet Air Cylinders. Air cylinders and heads are water jacketed. Steam cylinders neatly jacketed. These Compressors are furnished with governor, provided with automatic safety stop; and with pressure regulator and unloading device on air cylinders. Sight feed lubricators on steam and air cylinders, and all necessary oil cups. Foundation bolts and anchor plates. Foundation plans furnished with each Compressor.



Risdon Cross Compound Corliss Engine and Ring Inlet Air Cylinders

DIMENSIONS

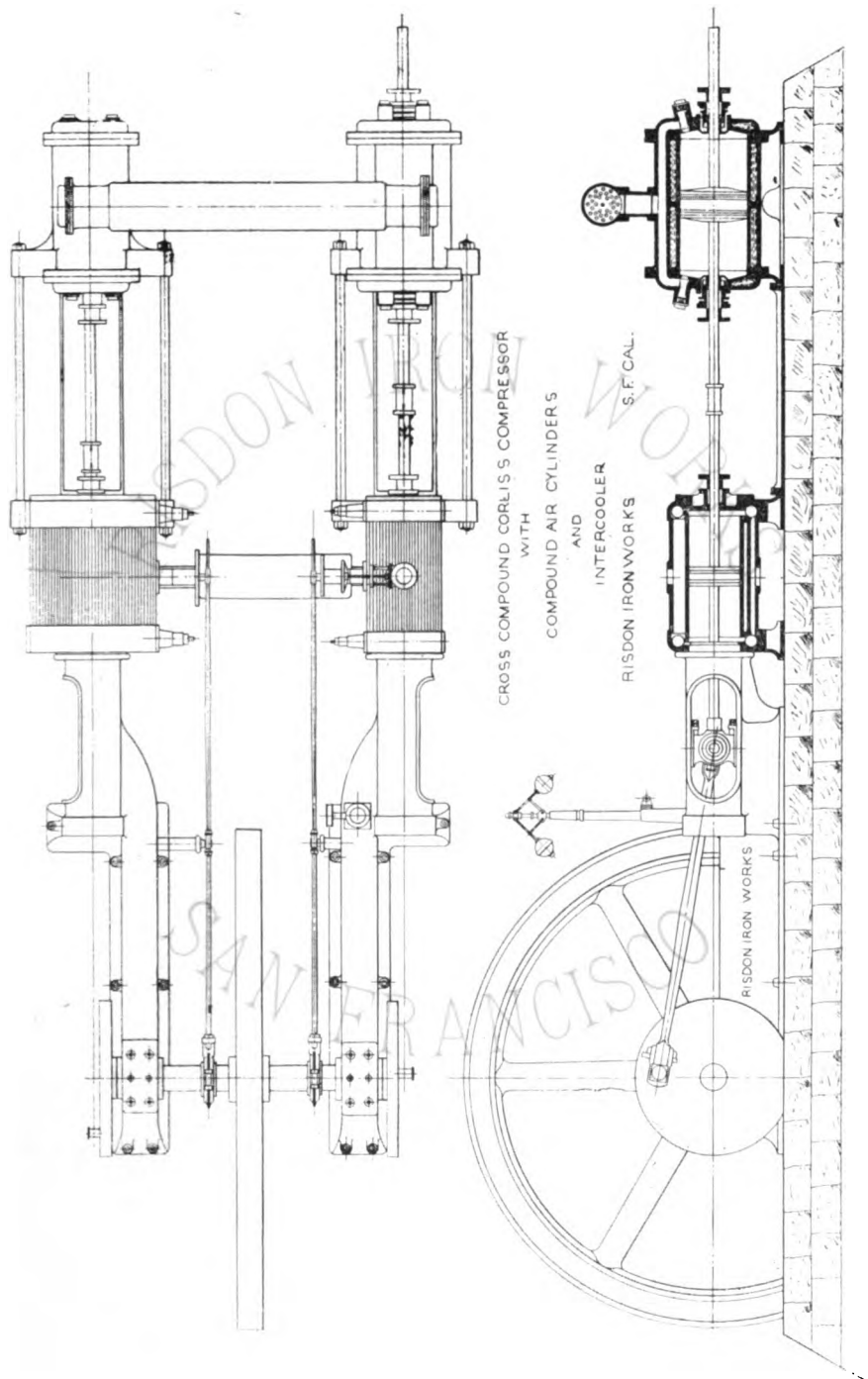
OF

Risdon Cross Compound Corliss

WITH

CROSS COMPOUND (2 STAGE) RISDON RING INLET AIR CYLINDER.

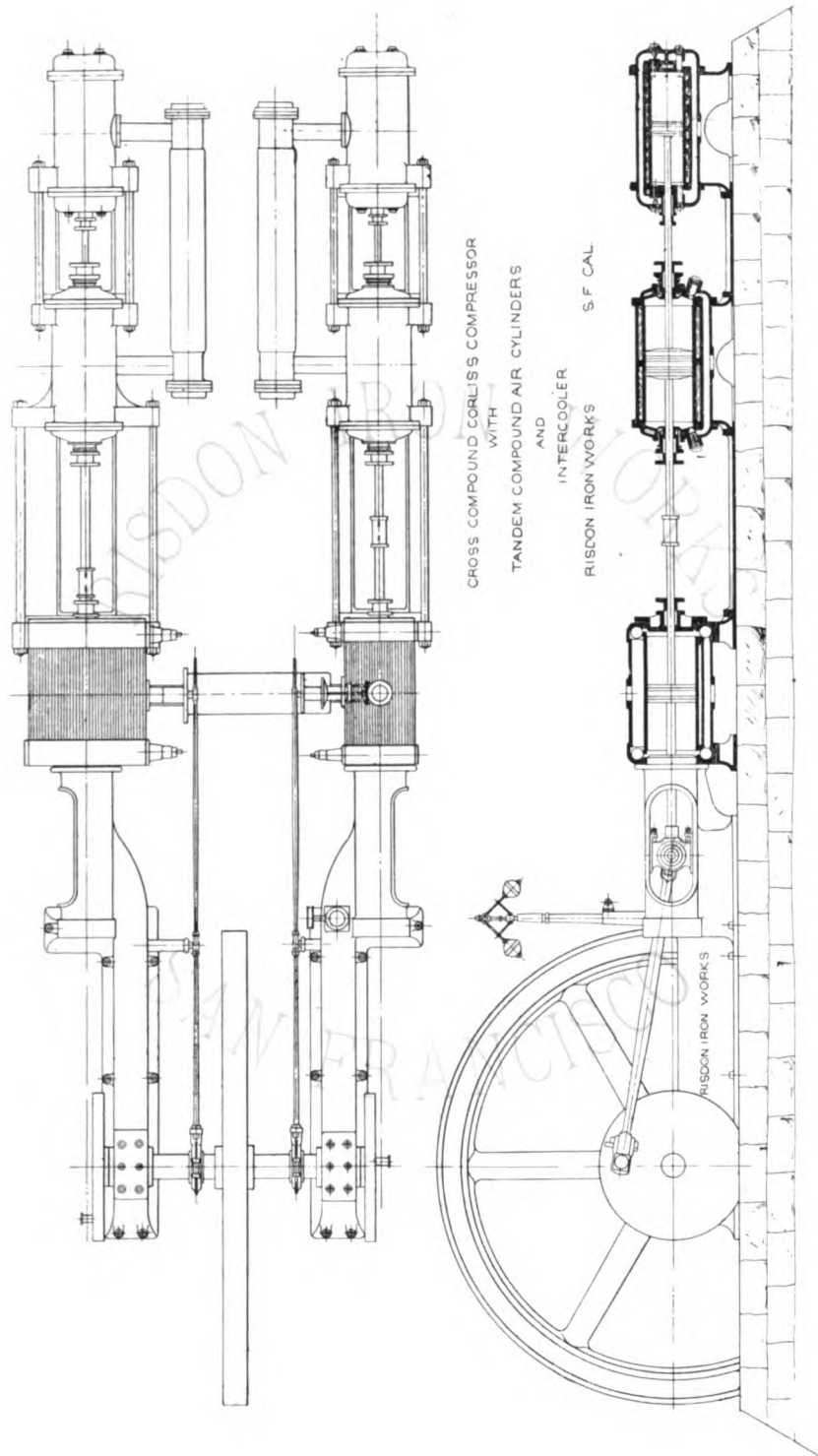
Size Number.	Sizes of Pipes. Inches.				Flywheel, Shaft Diameter.			Floor Space, Feet. (Not Allow- ing for Condensor.)	APPROXIMATE WEIGHTS.			
	Steam Pipe.	Exhaust Outlet.	Air Outlet.	Circulating Water.	Flywheel. Ft.	Shaft, In.			Flywheel.	Surface Condensor.	Jet Condensor.	Without Condensor.
						In Bearings.	Between Bearings.					
63	3	5	3	1	9	6	7	39 x 14	10000	51490	49990	45090
64	3½	5	3½	1¼	10	7	9	43 x 14	13500	63220	61720	57420
65	4	6	3½	1¼	12	7	9	47 x 14	15500	65620	64120	61070
66	4	6	4	1¼	10	7	9	43 x 14	16500	74840	74590	68140
67	4	6	4	1¼	12	7	9	47 x 14	18500	83040	81690	75140
68	4½	6	5	1¼	16	8	10	49 x 15	23000	103330	101080	94530
69	5	7	5	1¼	16	8	10	55 x 15	29000	116430	113780	107230
70	4½	6	5	1¼	16	8	10	49 x 15	23000	105980	103730	97180
71	5	7	5	1¼	16	8	10	55 x 15	29000	118430	115780	109230
72	5	7	6	1½	18	9	11	55 x 16	32500	139840	133840	126840
73	6	8	6	1½	18	10	12	56 x 16	33000	149000	141400	135408
74	6	8	6	1½	18	11	13	56 x 18	44100	169950	166250	155250
75	6	8	6	1½	18	11	13	56 x 18	44100	173300	169600	158600
76	7	9	6	1½	20	11	13	67 x 18	46500	201610	194510	183010
77	7	9	7	1½	20	12	14	58 x 19	50000	205200	195200	183700



Risdon Tandem Compound (2 stage and 3 stage) Compressors

We build all sizes of this style of Compressor, also Triple Expansion and Compound Steam Engines for operating same.

We also build all kinds of Vertical Compressors.

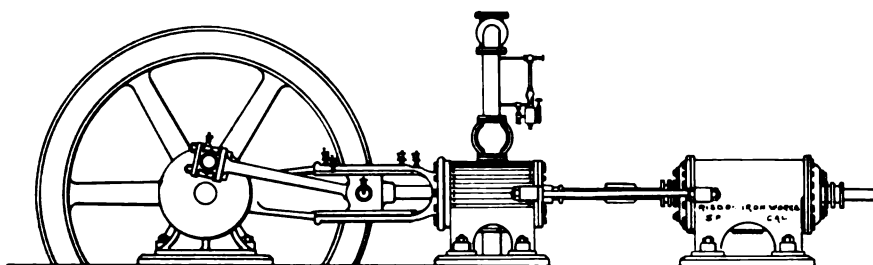
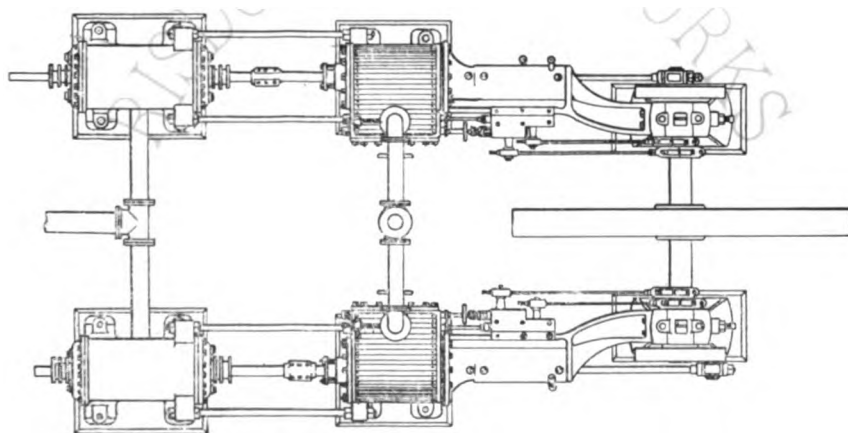


LIST OF SIZES
OF
Meyers' Cut-off Engines
AND
Risdon Ring Inlet Air Cylinders

As Illustrated on Page 27

No.	Size of Air Cylinder. Inches.	Revolutions per Minute.	Capacity in Drills. 3 5/16 Cyls.	Horse Power of Boiler Needed.	Diameter of Pipes.						Approximate Shipping Weights. Pounds.
					Steam.			Air.			
					Main From Boiler.	Branch to Each Cylinder.	Exhaust from Each Cylinder.	Main To Receiver.	Branch from Each Cylinder.	Total.	
64	10x16	Single.....	100	2	23	2		2 1/2	2 1/2		10000
65		Duplex.....	100	4	45	2 1/2	2	2 1/2	3	2 1/2	14000
66	12x16	Single.....	100	3	35	2 1/2		4	3 1/2		13000
67		Duplex.....	100	6	65	3	2 1/2	4	4	3 1/2	19000
68	14x24	Single.....	85	5	55	3 1/2		5	4		23000
69		Duplex.....	85	10	110	4	3 1/2	5	5	4	33000
70	16x30	Single.....	75	8	88	4		6	5		35000
71		Duplex.....	75	16	175	5	4	6	6	5	52000
72	18x30	Single.....	75	10	105	4		6	5		36000
73		Duplex.....	75	20	210	5	4	6	6	5	55000
74	24x48	Single.....	50	12	140	5		7	6		63000
75		Duplex.....	50	25	280	6	5	7	8	6	99000
76	28x48	Single.....	40	20	215	7		10	7		95000
77		Duplex.....	40	40	430	8	7	10	9	7	145000

MEYERS' CUT-OFF ENGINE



Risdon "Straight-Line" Air Compressors

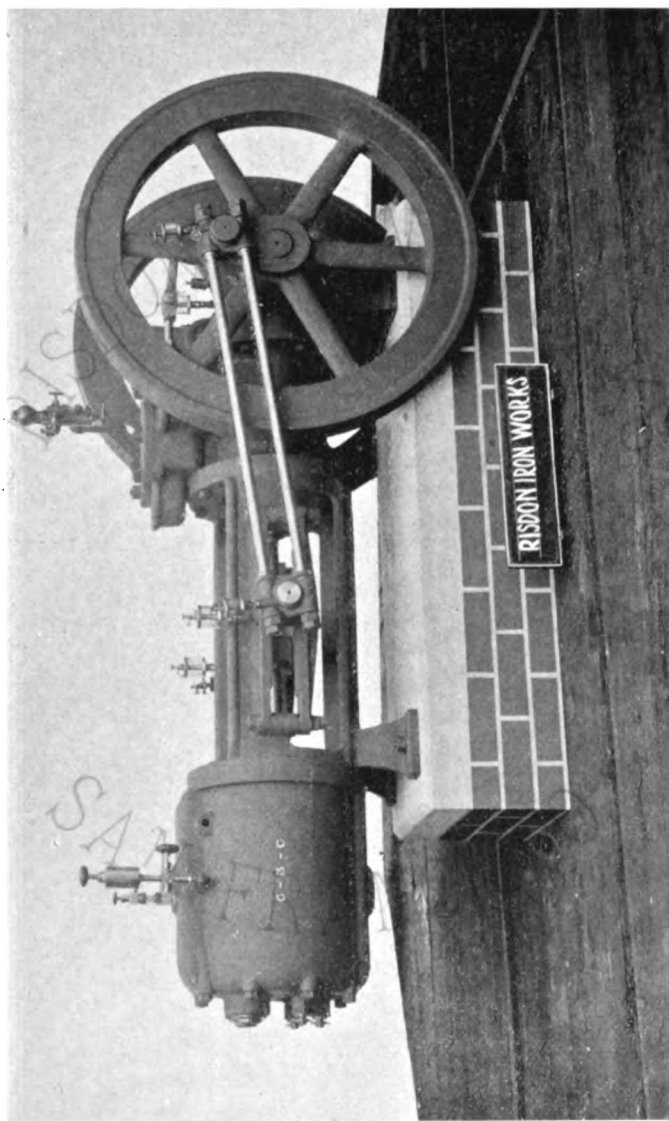
As per Cut Page 29

STEAM POWER AIR COMPRESSORS

No.	Cylinders.		Stroke.	R. P. M.	Capacity Free Air.	Air Pressure.
	Dia. Steam.	Dia. Air.				
79	10	10	10	150	123	50 to 80
80	12	12	12	150	225	50 to 80
81	12	14	12	150	303	30 to 60

WATER POWER, SAME STYLE

No.	Cylinders.		Stroke.	R. P. M.	Capacity Free Air.	Air Pressure.
	Dia. Steam.	Dia. Air.				
82	10	10	10	150	123	50 to 80
83	12	12	12	150	180	30 to 60
84	12	12	12	150	225	50 to 80
85	14	14	12	150	303	30 to 60



Risdon "Straight Line" Air Compressor

Risdon Water Impulse Compressors.

The cut on the opposite page and pages 33 and 35, made from the general plan of a 24x48 inch duplex, shows our latest and favorite design for a water-power compressor. An impulse water wheel mounted directly on the compressor shaft, and so designed with relation to the fall and quantity of water as to make the same number of revolutions that the compressor is expected to make, is the simplest way of applying the power of water to the compressing of air. The weight of the wheel is calculated so as to be sufficient to act as a fly-wheel. It will be found convenient to encase the wheel in a wooden box to keep the water from spraying around the compressor. The efficiency of these wheels has been tested to be as high as 95 per cent., and they can be relied upon to render in practice an efficiency of 85 per cent., which is applied directly to the compressor. For very low heads the water nozzle may be multiple so as to have two or more streams of water impinging on the wheel buckets.

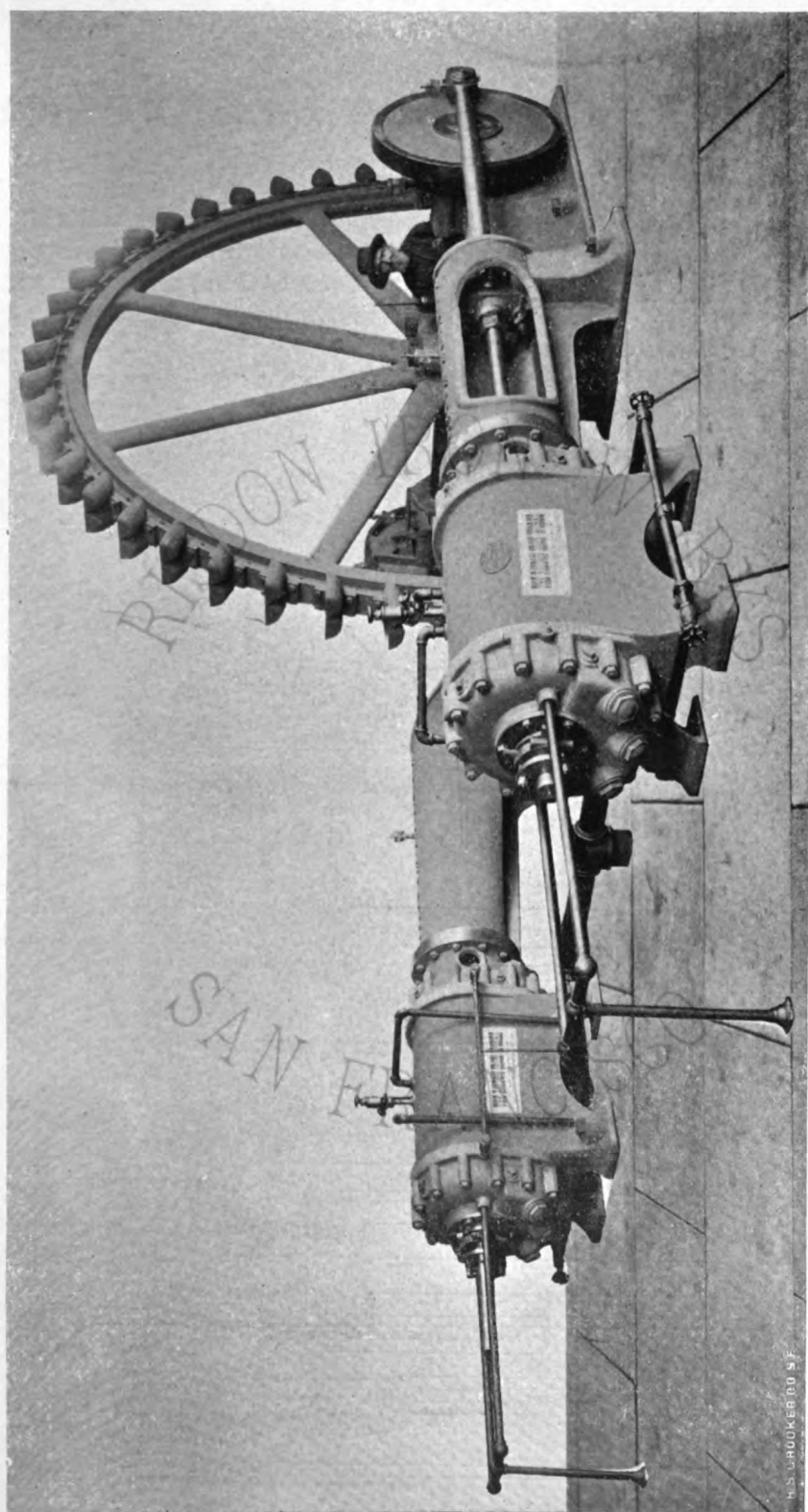
The advantages of this design are easily perceived: no belting, no gearing, no shaft transmission, and therefore no loss of power in transmission, and no liability to break down; besides, the wheel is in a position easy to get at.

The wheel is governed by an automatic shut-off, so that when pressure is at required point the water is slowly and automatically shut off, starting again when pressure falls.

LIST OF SIZES WATER POWER AIR COMPRESSORS.

Air Pressure 100 Pounds.

Size No.	Sizes of Air Cylinders.		Revolutions per Minute.	Piston Speed in Feet per Minute.	CAPACITY DUPLEX.		Indicated Horse Power. Duplex.
	Diam. In.	Stroke, In.			Cubic Feet. Per Min.	Free Air. Per Rev.	
	Air.						
86	10	30	90	450	547	6.080	110
87	12	30	87	435	684	7.865	138
88	14	36	85	510	1080	12.71	218
89	14	42	82	574	1116	14.83	244
90	16	36	82	492	1359	16.58	274
91	15	42	78	546	1509	19.34	304
92	18	36	80	480	1674	20.92	336
93	18	42	78	546	2061	25.76	382
94	18	48	75	590	1904	24.41	422
95	20	42	75	525	2093	27.90	454
96	20	48	72	576	2473	34.35	498
97	22	42	75	525	2718	36.24	546
98	22	48	72	576	2982	41.41	601
99	24	42	75	525	3211	42.82	646
100	24	48	70	560	3425	48.93	690
101	26	48	70	560	4033	57.62	813
102	28	48	68	544	4559	67.05	919
103	30	48	65	520	5015	77.16	1011
104	30	60	62	620	5980	96.45	1205
105	32	48	65	520	5718	87.97	1153
106	32	60	62	620	6817	109.96	1373
107							

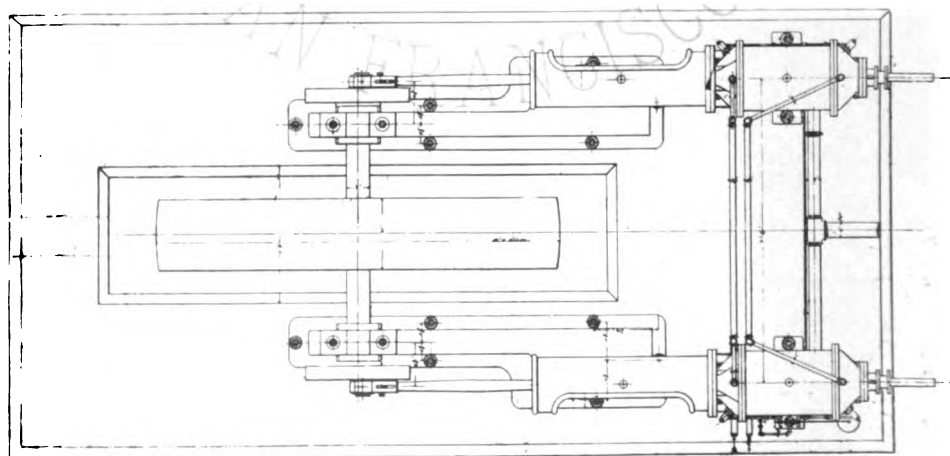
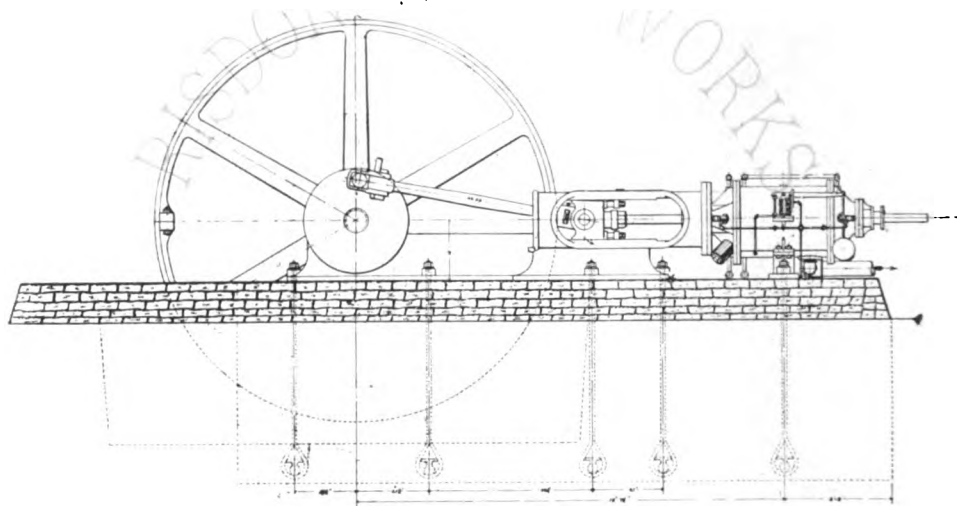


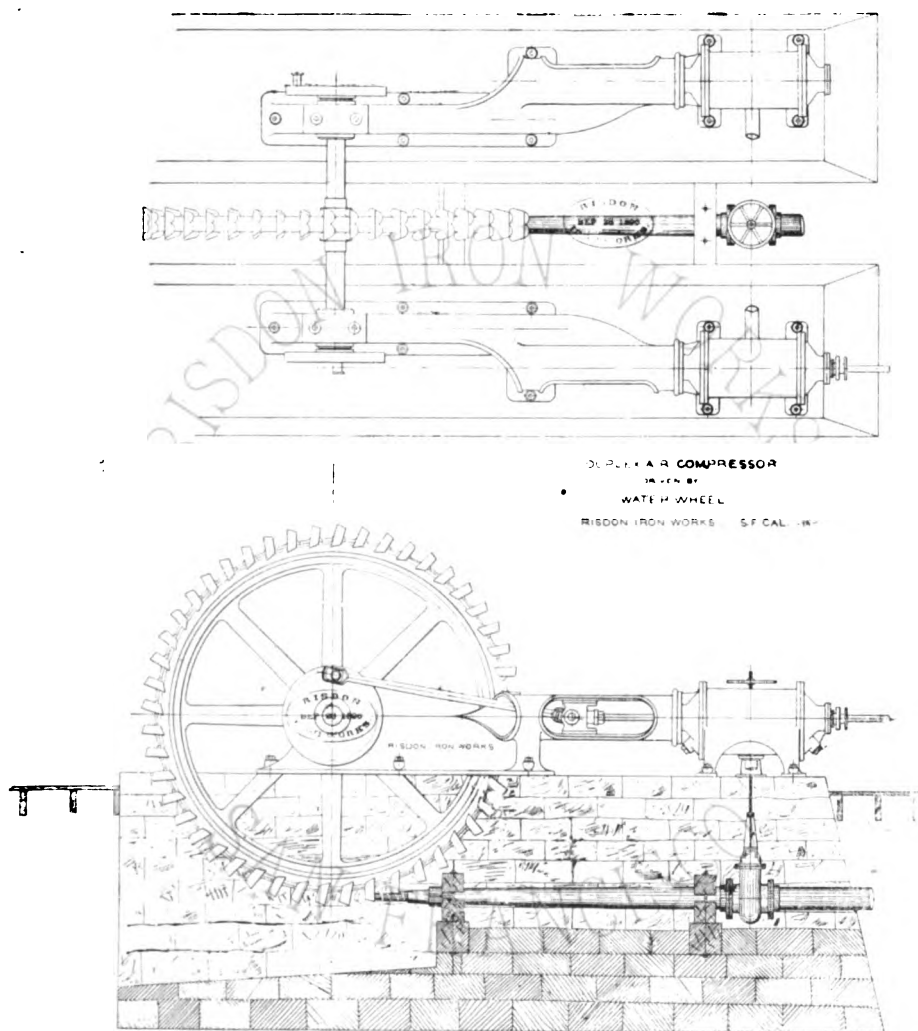
500 Horse Power Risdon Inlet Air Compressor, driven direct by Risdon Water Wheel, 24 ft. diameter.
Air Cylinder, 24 in. diameter, 48 in. stroke.

THE
JOHN CRERAR
LIBRARY.

Belt or Geared Air Compressor.

We illustrate on pages 37, 38, 39 one of our belt driven compressors, and while we advocate the use of direct connected water wheels or power to a compressor, sometimes this cannot be done, and an arrangement of this kind necessitates the use of belting, gearing or rope drive. All our compressors are equipped with our unloading device to control work.





24x48 Risdon Duplex Air Compressor

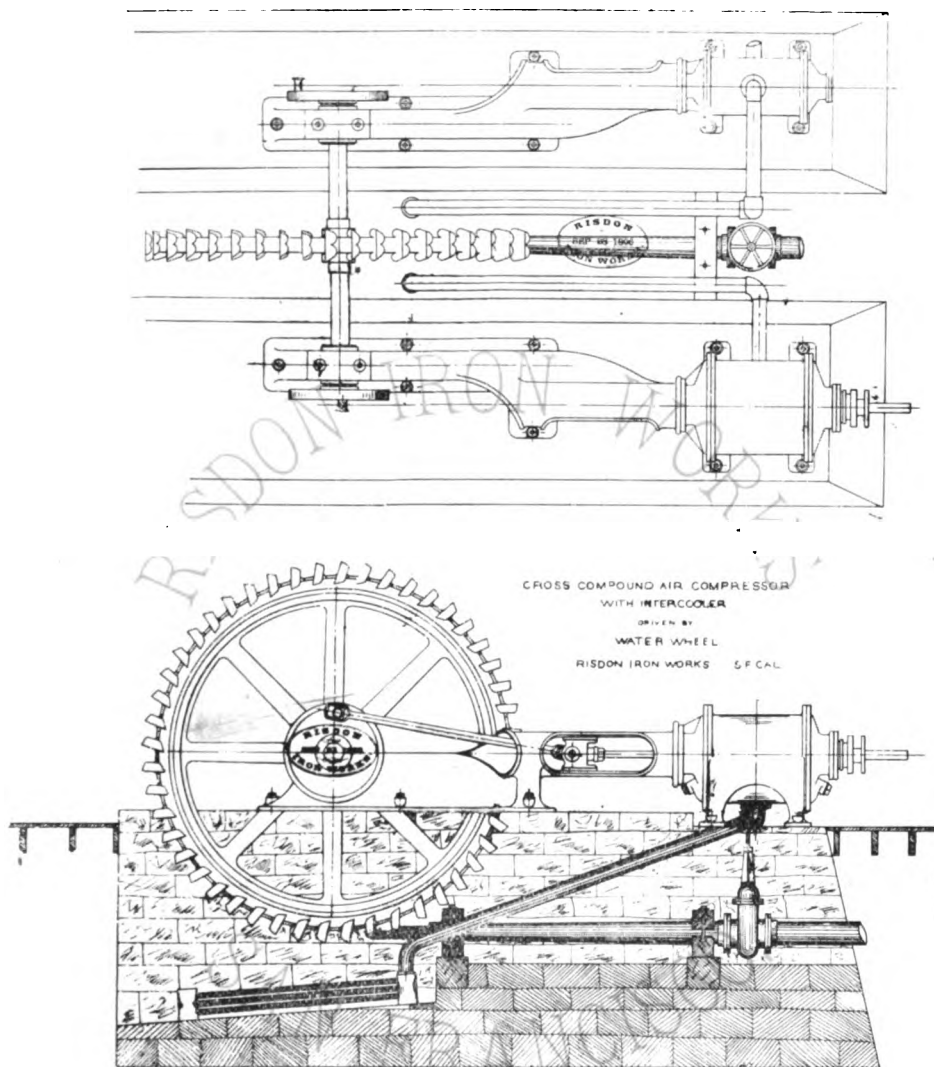
Risdon Water Impulse Air Compressor Compound, (2 stage) Air Cylinders

This Compressor, illustrated on page 35, is of the same general description as the single stage illustrated on page 31, except that the air cylinders are compound with intercoolers, and is a very efficient machine. We recommend this type when pressure runs above 100 lbs., or when water has to be purchased.

LIST OF SIZES

Air Pressure 100 lbs.

No.	Size of Air Cylinders in Inches.		Stroke.	Revolutions per Minute.	Pis on Speed in Feet per Minute.	Capacity.		I. H. P. of Comp.
	Diameters.					Cubic Feet Free Air.		
	Low Pressure.	High Pressure.				Per Minute.	Per Revolution.	
108	16	10	30	90	450	571	6.35	97
109	18	11	36	85	510	889	10.46	152
110	18	11	42	82	574	1000	12.20	170
111	22	13	36	85	510	1325	15.60	225
112	22	13	42	82	574	1489	18.12	253
113	24	14	42	78	546	1670	21.41	284
114	24	14	48	75	600	1834	24.46	312
115	26	15	42	78	546	1980	25.21	337
116	26	15	48	75	600	2160	28.81	367
117	28	17	48	75	600	2513	33.52	427
118	30	18	48	72	576	2777	38.58	471
119	32	19	48	72	576	3160	43.98	540
120	34	20	48	72	576	3558	49.44	604
121	34	20	60	65	650	4016	61.79	685
122	36	22	48	70	560	3904	55.78	664



**Risdon Direct Driven Water Impulse Air Compressor
with Compound (2 stage) Air Cylinders
and Intercooler.**

Low Pressure.....42 inch diameter

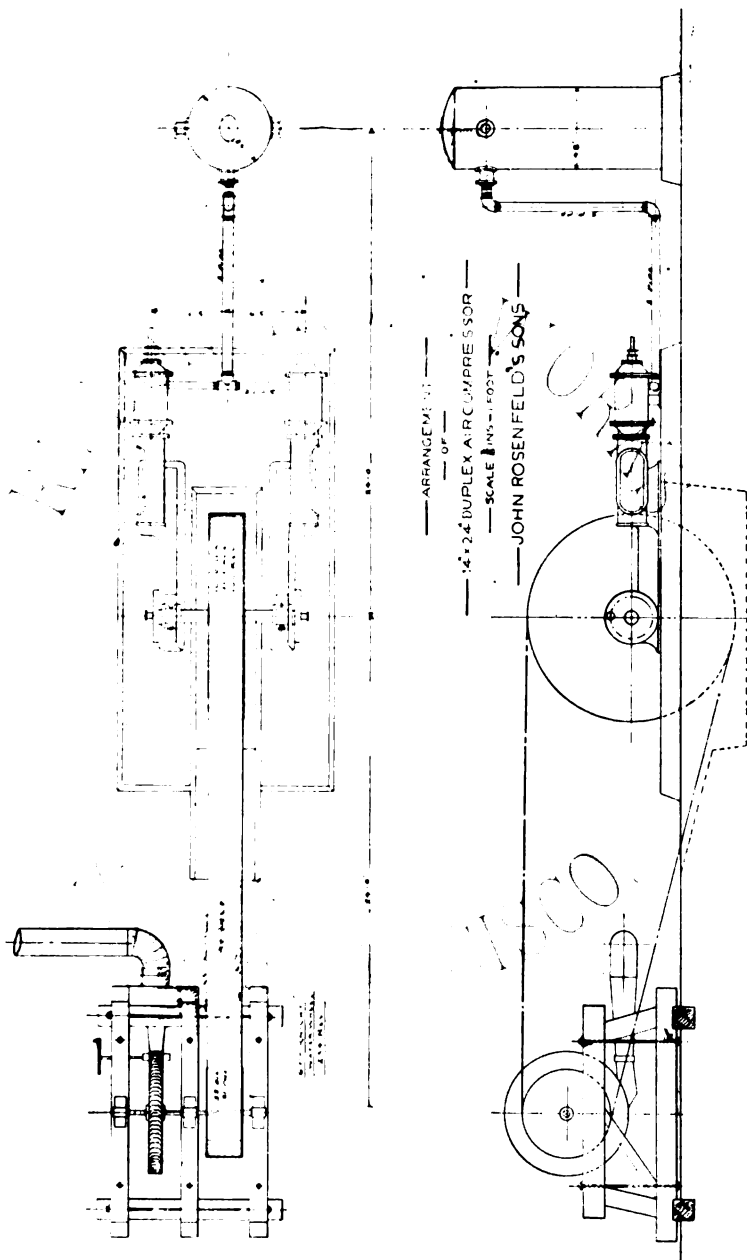
High Pressure.....24 inch diameter

Stroke.....48 inch diameter

List of Sizes Belt or Geared Air Compressors.

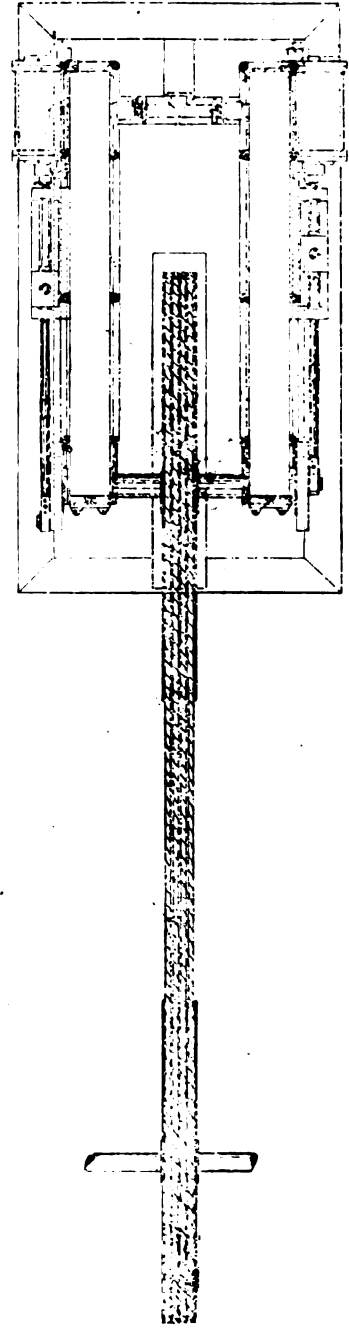
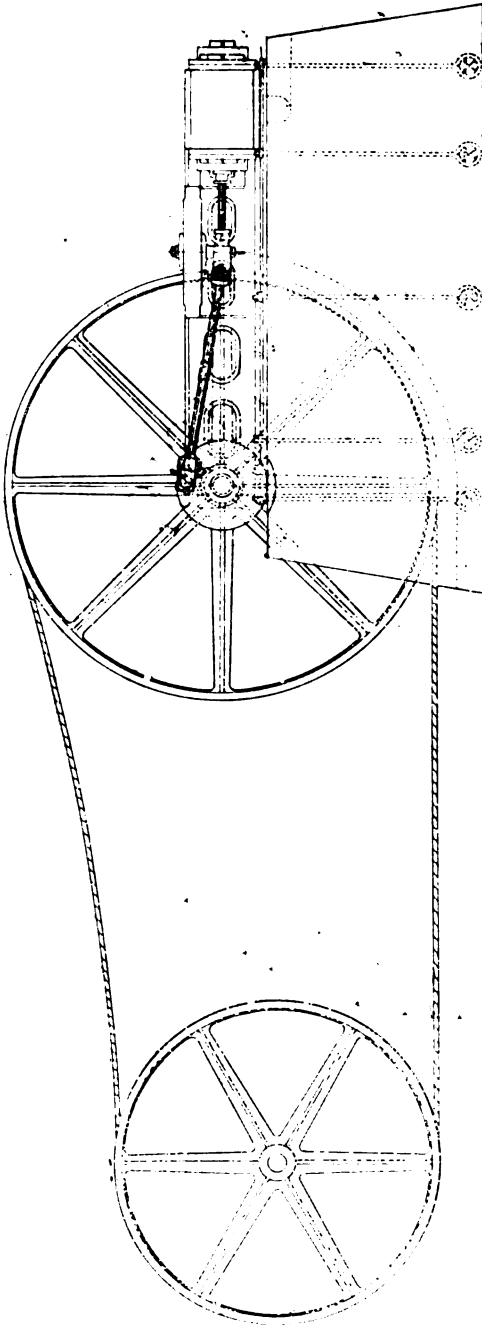
No.	Size of Air Cylinder		Revs. per Min.	Capac. No. 3 Drills.	H. P. Water Wheel.	Size of Pulley.	
						Feet.	Inches.
124	10x16	Single.....	100	2	23	6 x	13
125		Duplex.....	100	4	45	6 x	13
126	12x16	Single.....	100	3	35	6 x	19
127		Duplex.....	100	6	70	6 x	19
128	14x24	Single.....	95	5	60	10 x	21
129		Duplex.....	95	10	120	10 x	21
130	16x24	Single.....	90	7	80	12 x	25
131		Duplex.....	90	14	160	12 x	25
132	18x30	Single.....	80	10	120	12 x	36
133		Duplex.....	80	20	240	12 x	36
134	20x30	Single.....	80	12	140	14 x	36
135		Duplex.....	80	25	280	14 x	36

If spur gear and pinion are required, an additional price will be added.

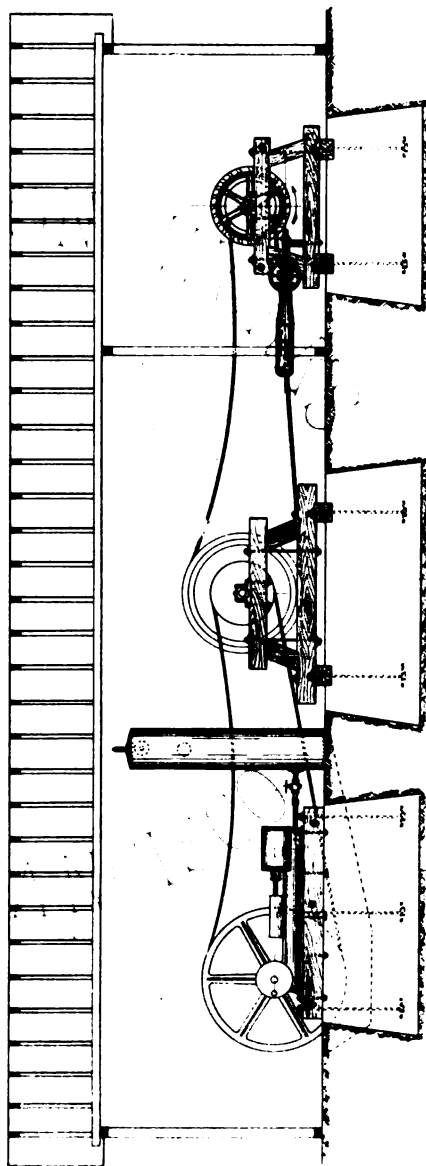
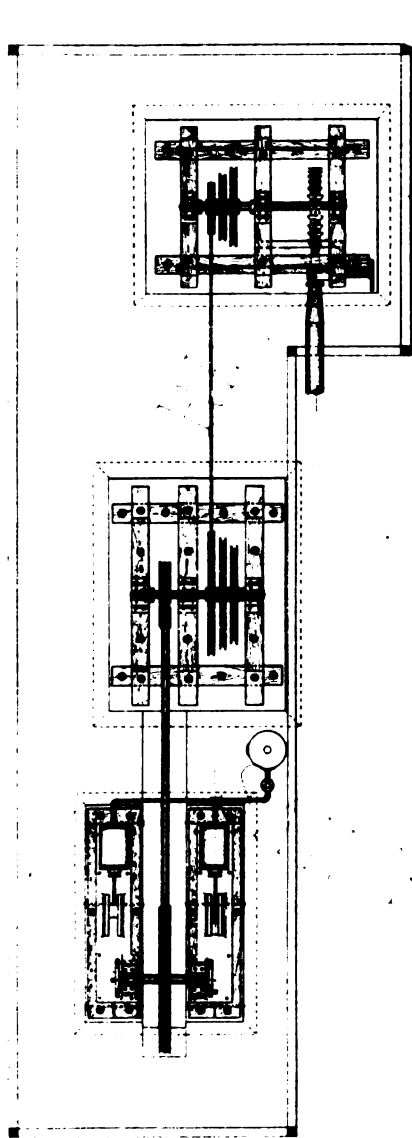


Belt Driven Risdon Ring Inlet Air Compressor. Sizes on Page 36.

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Rope Driven Risdon Ring Inlet Air Compressors. Sizes on Page 36



Double Speed Reduction Rope Driven Ring Inlet Air Compressor—3-speed. Sizes Page 36

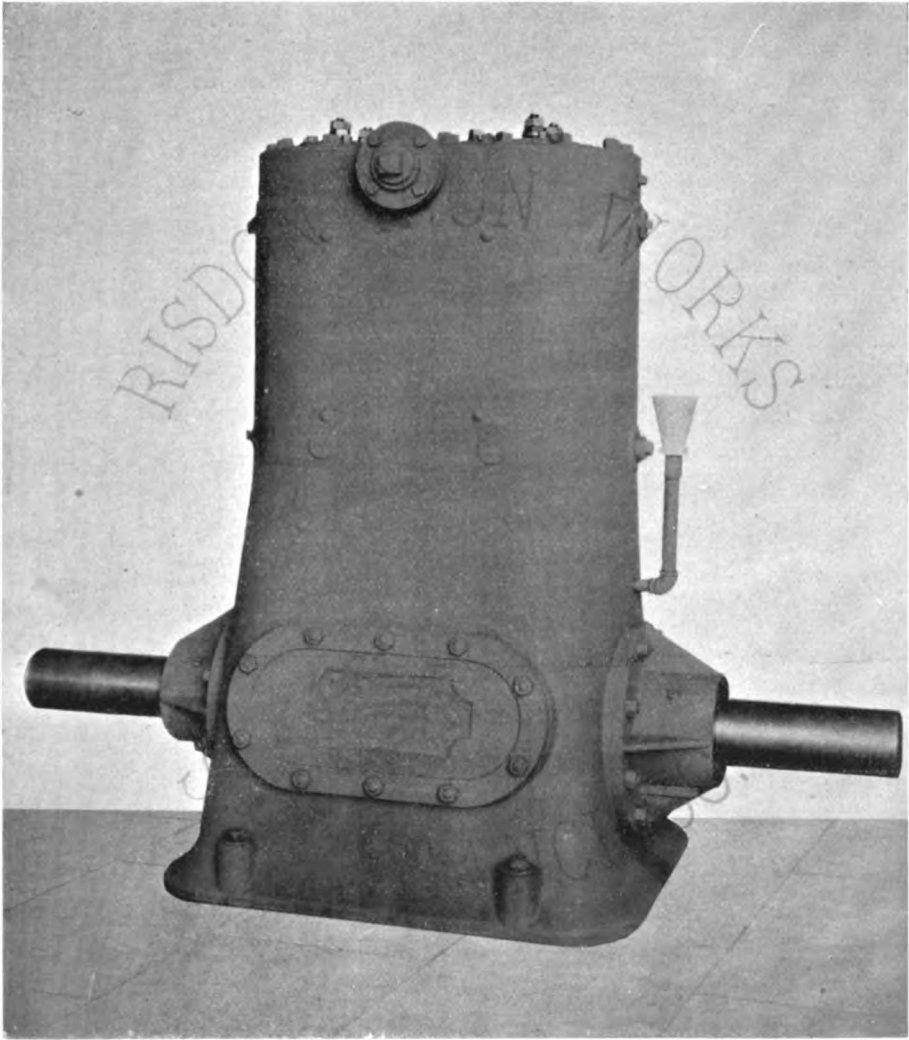
Belt or Water Wheel Compressor for Small Plants

These Compressors are of the Duplex, Single Acting Type, and are very simple and efficient. They are completely water-jacketed, and have exceptionally large valve areas, and have given the most satisfactory results. The cranks run in a mixture of oil and water in the enclosed crank case; the splashing of the crank in this oil lubricates all parts of the machine, including main bearings, cranks, cylinders and wrist pin, so that the machine requires no attention, and does away with the necessity of putting oil into the cylinder with its objectionable feature of forcing oil gas into the mine.

These machines are strictly first-class in every detail of design, material and workmanship, and the different sizes give ample air to run the drills specified.

RISDON AIR COMPRESSORS.

No. of Compressor.	Diam. of Cylinder.	R. P. M.	No. of "D" or 3 5-6 Inch Drills, for which Comp. will give plenty of air at revolutions given.	No. of "A" or 2 1/4 Inch Drills, for which Comp. will give plenty of air at revolution given.
137	6 1/2 x 8	150		1
138	8 x 10	150	1	2
139	10 x 10	150		3
140	11 x 12	150	2	5



Belt or Water Wheel Compressor for Small Plants.

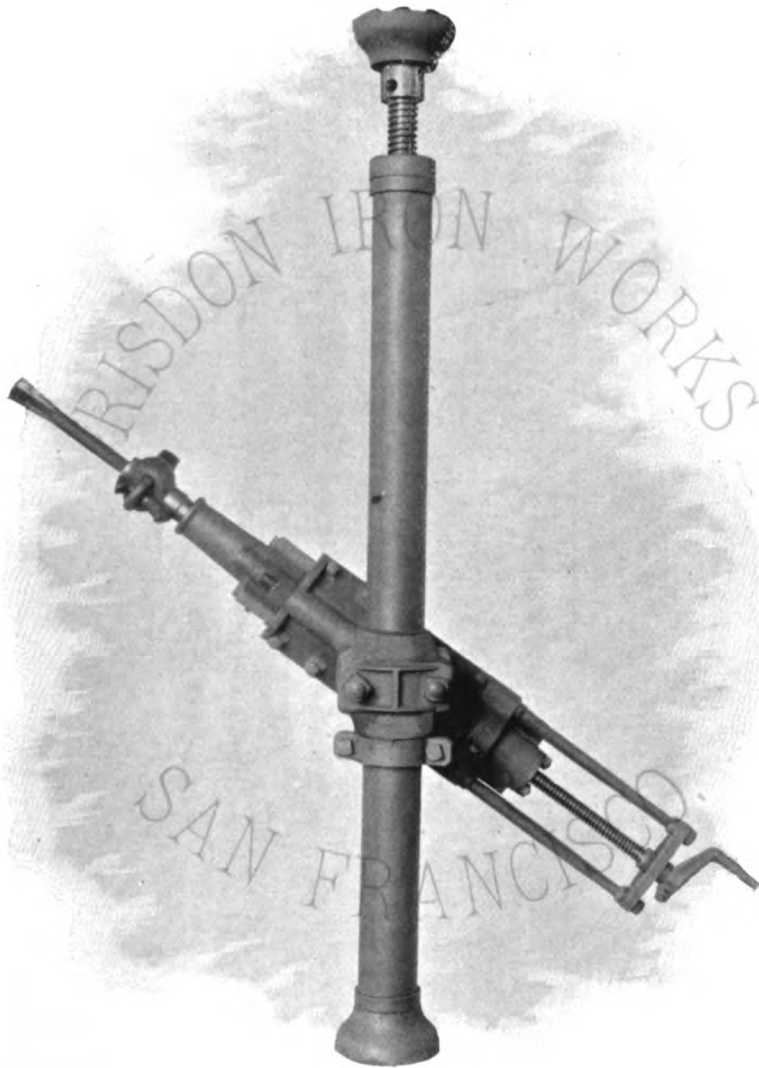
Sizes Page 40.

RISDON AIR DRILLS

The "RISDON" IMPROVED DRILLING MACHINE is the outcome of a series of carefully conducted experiments covering a period of five years. During this time all of the leading American and European makes of Rock Drilling Machines were carefully examined, their good points being fully appreciated, while their weaknesses were specially noted. The motive prompting this investigation was the desire to perfect a Rock Drilling Machine that would be specially adapted to meet the severe requirements in drilling the hard rock encountered in the mines on the Pacific Coast.

During their investigation special attention was given to the opinion of the users of Drilling Machines, their experiences being considered an excellent guide in not only appreciating what was required of "The Ideal Drilling Machine," but in also selecting the desirable features of the several leading types of machines at present in the market, but principally to learn of their defects and weaknesses so as in designing the "Risdon" Machine to eliminate these defects as far as possible.

These investigations not only considered the points just mentioned, but also included the designing and making of a number of machines, these machines being fully tested in the Works, and their apparent objections and weaknesses reminded, and then an extensive test at actual mining work. As soon as any defect developed, the machine was returned to the Works, and the defect located and overcome. The result of these very careful experiments has been the development of a drilling machine which is designed and built on the proper lines, and which is the simplest, most durable and economical machine on the market—in fact being a matter of evolution—"The Survival of the Fittest."



Risdon Improved Air or Steam Rock Drill.

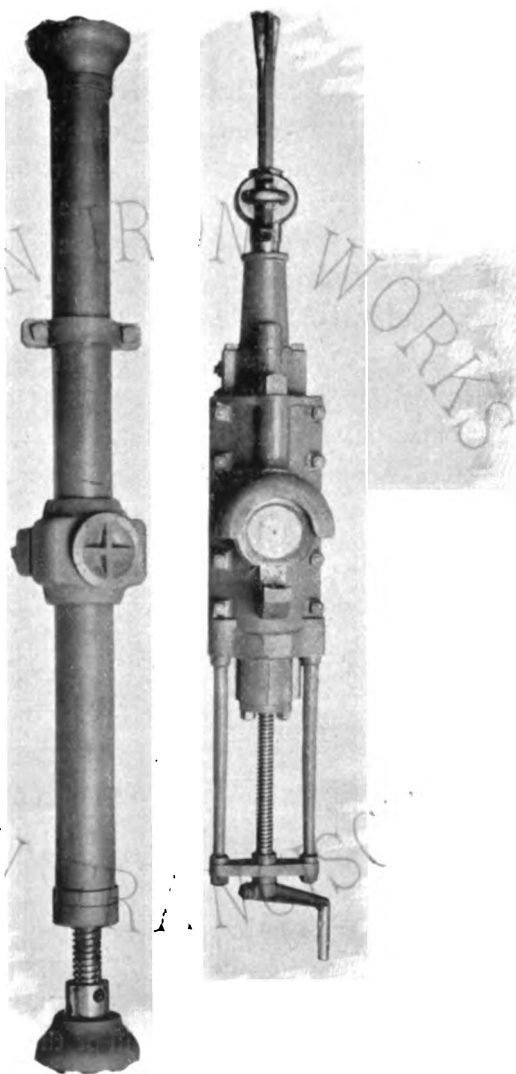
Continued from page 42.

In designing this machine the following requirements of a good Rock Drill, taken from the work of Andre on "Coal Mining," were carefully considered, viz.:

1. A machine rock drill should be simple in construction and strong in every part;
2. It should consist of few parts, and especially of few moving parts;
3. It should be as light in weight as can be made consistent with the first condition;
4. It should occupy but little space;
5. The striking part should be of relatively great weight, and should strike the rock directly;
6. No other part than the piston should be exposed to violent shocks;
7. The piston should be capable of working with a variable length of stroke;
8. The sudden removal of the resistance should not be liable to cause an injury to any part;
9. The rotary motion of the drill should take place automatically.

The following description, with the aid of the illustration, will be of assistance in appreciating the many points of merit of this machine:

WEARING PARTS—The machine is simple in every part, and is entirely free from cams or tappets of any description—in fact it consists of only *two quick moving parts*, the piston and valve, and these, as well as other parts, are very substantial. In the D size machine the *Piston Rod* is 2 1-4 inches Diam., whereas in other makes of machines of this size the Piston Rods are only 1 5/8 inches and 1 3/4 inches in diameter. This heavy Piston Rod has many advantages, especially in drilling through seamy ground or through extremely hard rock where there is a heavy, racking strain on the piston.



Risdon Improved Rock Drill With Column and Clamp.

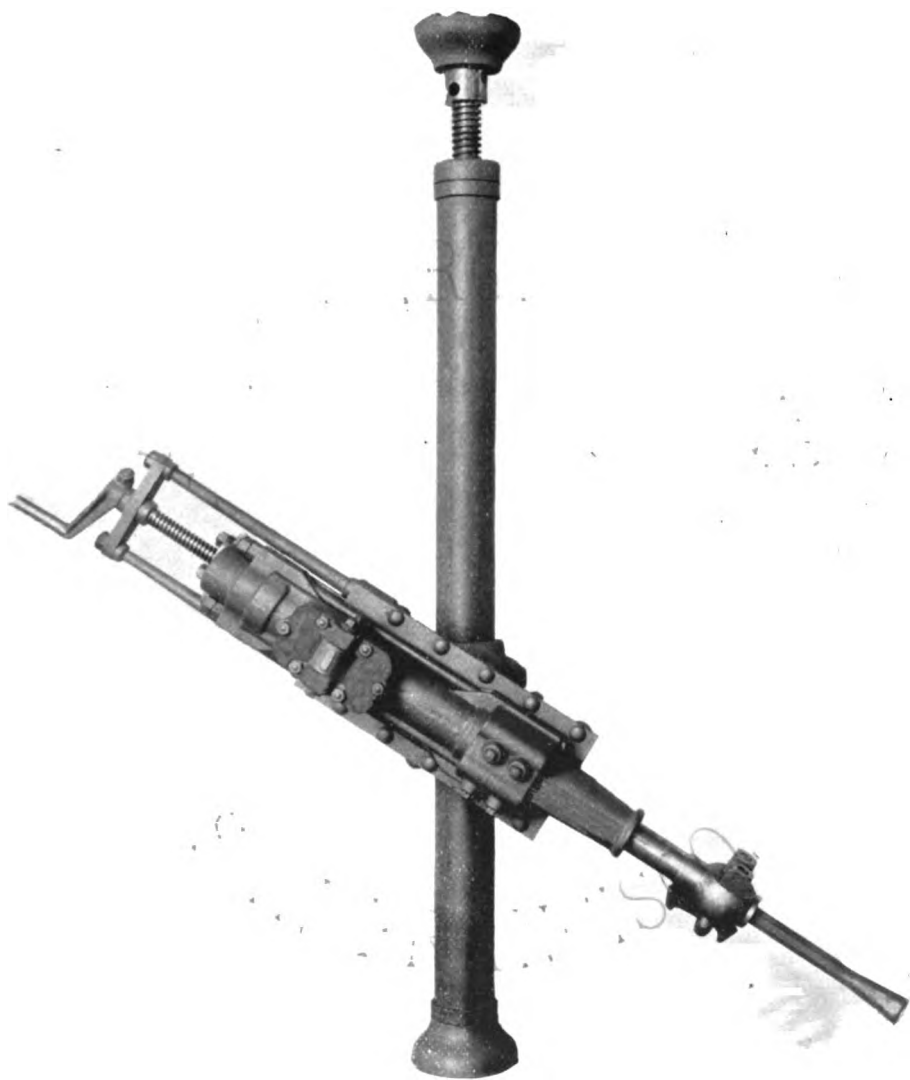
Continued from page 44.

PERFORMANCE—This has been recently demonstrated in driving a tunnel near Waterford, on the Tuolumne River, which was being driven through a serpentine and flint deposit—being the hardest rock in California. In starting this work drills of one of the leading makers were used, but owing to the extreme hardness of the rock, these machines were a continual source of annoyance and expense, as the piston rods would break off, and the machines were in the shop for repairs the greater part of the time.

A “Risdon” machine was then put in this tunnel, and has been in continuous service (at the time of writing) for over four months without any repairs whatsoever, the air pressure used being 100 to 120 lbs. per square inch, and the “Risdon” Drill is regularly averaging 10 and 12 holes, 5 feet deep, per shift, in this rock.

VALVE—The valve is a small, very light, balanced valve, entirely independent of the piston, and does not move until the blow has been struck—making this, in reality, a “Dead Stroke Drill” (without any cushion whatsoever). The valve is in reality perfect, and does not wear; some of these, after having been in constant heavy use for more than a year, have been compared with the original gauges and were up to the original dimensions, showing that no wear had taken place, which is an essential feature in drilling machines.

CHANGE OF STROKE—Owing to the independent valve arrangement, the *Piston has a variable stroke*, and will operate perfectly from *half stroke to full stroke*. This is a great advantage in starting a hole, as the machine need only be brought up close to the work by turning the feed-screw crank, and then when the hole is well started can be drawn back to full stroke; this saves one half the time in starting a hole over that required by a drill of the tappet type that will operate



Risdon Improved Rock Drill and Column.

Continued from page 46.

only at about full stroke. Another advantage of the variable stroke is that it enables the drill to work in seamy or broken holes.

PISTON—In this drill the piston is the only part subjected to violent shocks; and as it is so much heavier than is usual in standard practice, it withstands this duty without any difficulty. In addition, owing to the superior guide formed by the solid front head, and the design of the piston, it does not bring excessive wear on the drill cylinder, which shows apparently no wear after long and severe service.

BACKING—The drill has a backing power, a recovery equal to its blow, which is of the greatest importance in preventing the drill bit sticking in seamy or broken ground. In this respect the "Risdon" Drill is very much more powerful than any other machine.

ROTATING MOTION—The rotary motion is in the front head, and is applied direct to the piston rod in such a manner as to make a most substantial arrangement, and is entirely different from other machines which use a hollow piston rod and depend upon a frail rifle bar to turn the piston; whereas in the "Risdon" Drill the large piston rod itself takes the place of the rifle bar, and the rotary nut is made of a special bronze, and is prevented from turning back by two tempered steel pawls 4 inches wide. This part of the machine is one of its greatest points of advantage over any other machine.

CUSHIONING—The piston is cushioned on its return stroke by a novel air cushion which takes the place of rubber bumpers or steel springs, and most successfully checks the return stroke of the piston; and, in addition, the energy expended in compressing the air in the cushion is given out again in useful work in driving the piston on its forward or drilling stroke. This feature adds materially to the rapidity and force of the striking blows.

CONVENIENT—The machine is most convenient in all its details. To



RISDON DRILLS

SIZE D, SERIES G.

remove the machine from the column, tripod or quarry bar it is only necessary to slacken one nut, it not being necessary to remove a nut or bolt; and, owing to the special design of the shell, the nut clamping the machine to the column, tripod or quarry bar is always in a most convenient position for the chuck tender, i. e., at the front end of the machine. This clamping device is worthy of more than passing notice; its simplicity and convenience, as well as its positive holding qualities, are admired by all mining men of experience.

CHUCK—The device for holding the drill steel in the piston is an arrangement that has given excellent results. In addition to the V bolt and nuts, a tapered gib or key with heads at each end, is inserted between the chuck block and under the V bolt. To clamp the drill steel it is only necessary to drive forward this key; to release the drill steel, drive back the key. This saves much time in changing drill bits, and also prevents the breaking of V bolts. It has a further advantage, in that it prevents the drill steel jarring loose in the piston, as the tendency is for the key to be driven up tighter by the striking of the bit on the rock.

DUPLICATE PARTS—All parts of these machines are made with special machinery, and are made to standard gauges, which insure perfect accuracy of interchange of parts.

MATERIAL AND PATENTS—The material used is absolutely the best for the purpose for which it is used, and the workmanship is of the highest class. The many points of merit of the "Risdon" Machines are fully covered by Letters Patent of the United States, and by Patents pending.

CONSUMPTION OF AIR—Owing to there being no long air passages in this machine, as in other machines, which require to be filled, each stroke with air that gives out no useful work, the consumption of air is less for the actual work done than in any other machine. The strokes are also much more rapid, for the same reason.

DRILLS—All our drills use Octagon Steel, without any blacksmith work on chuck ends.

Risdon Improved Rock Drills

SPECIFICATIONS

LETTER INDICATING SIZE.....	A	D
Diameter of Cylinder.....	2 $\frac{1}{4}$ in.	3 5-16 in.
Length of Stroke.....	5 in.	7 in.
Size of Air Hose.....	$\frac{3}{4}$ in.	1 in.
Weight of Drill unmounted.....	128 lbs.	285 lbs.
Approximate strokes per minute with 60 lbs. pressure at Drill.....	700	500
Depth drilled without changing Bits.....	17 in.	24 in.
Depth of vertical hole each machine will easily drill.....	5 ft.	14 ft
Diameter of holes Drilled.....	1 to 1 $\frac{5}{8}$ in.	1 $\frac{1}{4}$ to 2 $\frac{1}{2}$ in.
Size of Steel used.....	$\frac{7}{8}$ oct.	1 $\frac{1}{8}$ oct.
Size of shanks.....	$\frac{7}{8}$ oct.	1 $\frac{1}{8}$ oct.
No. of Drills per set to drill to depth given.....	5	8
Approximate weight of one set to drill vertical holes of depth given.....	44 lbs.	241 lbs.
Horse Power of Boilers required to run by Steam direct.	5 H. P.	10 H. P.
Size of Pipe required for 100 to 200 feet.....	$\frac{3}{4}$	1

Price List "Risdon" Drills

LETTER INDICATING SIZE.....	A	D
Price of Drill, Unmounted, without tripod or column	\$170.00	\$275.00
Price of adjustable tripod, complete.....	30.00	40.00
Price of Single Screw Shaft or Tunnel Bar, <i>with</i> clamp, 6 to 8 feet long.....	30.00	40.00
Price of Double Screw Tunnel Bar, <i>without</i> clamp and arm, 6 to 8 feet long, for D drill only....		28.00
Clamp for Tunnel Bar.....		13.00
Adjustable Arm Tunnel Bar.....		16.00
Quarry Bar for Gadding, Channeling, etc.....	175.00	250.00
Set of 5 Blacksmith's Tools for Dressing and Machining Drill Bits.....	7.50	10.00
50 feet Best Guaranteed Flat Steel Armored .5-ply Hose, complete with Doble Perfected Couplings.....	33.00	37.00

Send for Discounts

DRILL STEEL

PRICE LIST

A. MACHINE.

7/8 OCT. DRILL STEEL.				PRICE.		
Depth of Hole Drilled by each Set of Steels.		No. of Steels in Set.		American.	Manganese.	Firth's Best English
Pounds	Ft.	In.				
4 1/4	1	6	1	\$ 1.75	\$ 1.95	\$ 2.25
10 1/2	2	6	2	3.65	4.20	4.95
20	3	4	3	5.75	6.75	8.90
30	4	6	4	8.00	10.20	12.40
44	5	6	5	10.40	13.20	16.65

D. MACHINE.

1 1/8 OCT. STEEL.						
9 1/2	2	0	1	2.50	3.00	3.70
24 1/2	3	6	2	5.40	6.75	8.60
45	5	0	3	8.75	11.30	14.50
71	6	6	4	12.50	16.50	21.50
103	8	0	5	16.50	22.50	29.60
141	10	0	6	21.50	29.50	39.50
188	12	0	7	26.50	37.50	50.50
241	14	0	8	32.50	46.50	62.90

This length is in addition to Shank.

Send for Discounts.

Directions for Operating Risdon Rock Drills

Care must be taken to have the mountings secure and firm ; this cannot be looked after too carefully.

In setting a column use a piece of plank several inches thick (4 to 6 inches), about 2 feet 6 inches long by 9 to 12 inches wide on the bottom of heading or tunnel ; place the cups on this plank, set the points of jack screws in same, straighten column, putting a piece of plank on head of same, fill in the space between roof and head with blocks and wedges, so that when the jack screws are tightened the head board will bear evenly on head of column ; next place safety clamp on column at proper height, then place arm on top of safety clamp, then attach drill clamp or chuck to arm, then mount drill in chuck, and after putting in starting bit and setting drill in proper position for hole, tighten all bolts firmly, especially arm and clamp bolts.

In starting a hole in an oblique surface, time will be saved by spawling off a spot large enough to allow the bit to start straight on a flat surface, otherwise the sharp cutting corner of bit will be worn off, permitting bit to glance, thus throwing unnecessary strain on the machine without any compensating gain.

In setting a shaft bar use planking at both ends, well wedged and leveled up. Attach main clamp and drill direct to shaft bar without using arm.

In setting tripod it is well to sink holes for points of same with a gad from $\frac{1}{2}$ inch to $\frac{3}{4}$ inch, so they will not slip.

To change drill from right to left side, or vice versa, on tunnel column, move main clamp to end of arm, loosen set nut and arm bolts, thereby permitting turning of drill in chuck.

If necessary to drill lower or bottom holes very flat turn drill under arm, as the Risdon Drill will work equally well bottom side up, or in any other position.

In starting holes, feed machine up so as to shorten stroke to 2 or 3 inches as nature of rock and shape of face may require ; this gives a short light, blow, making the starting of a hole easy and quick. Drill runners will appreciate this point, which is a feature peculiar to this drill.

KEEP THE MACHINE WELL OILED, particularly a new one, which should be oiled while running at least every half hour the first few days.

Keep piston rod well oiled, so that friction in stuffing box may be reduced to a minimum. Oil should be applied in front of stuffing box in small quantities and at short intervals.

Oil piston and valve at a point between throttle valve and main valve of drill. When oil is so applied the air or steam carries it through the machine, lubricating all the inner working parts more thoroughly than can be done in any other way.

Oil should be put in the back head occasionally, that it may more thoroughly lubricate the rotating mechanism.

DO NOT USE BLACK OIL OR CYLINDER OIL when using compressed air as power, but a light engine oil, or what is STILL BETTER, OUR AIR DRILL OIL, prepared especially for this purpose.

When using steam for power use best cylinder oil.

NEVER USE VEGETABLE OR ANIMAL OIL UNDER ANY CONSIDERATION if it can possibly be avoided.

Wipe off shank of drill, and be sure that it rests firmly in bottom of chuck before tightening chuck bolts. Chuck bolts should be tightened thoroughly and evenly. It is a common practice among many drill runners to tighten one chuck bolt nut before tightening the other. This is wrong and will surely result in an unnecessary number of broken chuck bolts.

The Risdon Drills are all thoroughly tested before shipment, and the parts are fitted closely; for this reason the drill may work a little stiff for the first few days. Should this be the case, pay particular attention to directions for oiling.

The feeding of the drill depends upon the speed with which the bit cuts into the rock; if fed too fast the stroke is shortened; if fed too slow the piston will strike the front head or buffer; in either case the machine is expending its power upon itself instead of upon the rock, so that the proper feeding is necessary to get the best results from a drill.

The proper feeding of a drill can only be acquired by experience and close attention on the part of the operator. The machine should be fed just fast enough to give the piston very nearly its full stroke, except when starting a hole or crossing a seam or seamy spot in the rock.

The best drill runner is the one that not only knows how to put in holes, but who takes care of his machine, and on the drill runner to a large extent depends the size of the repair bill. If a drill runner will watch his machine, keep it oiled, and if a nut or bolt gets loose attend to it at once, he will frequently save a break-down.

The main qualifications of a good drill runner are judgment and experience; he must be a careful man, of patience and energy. A careless, shiftless man is an expensive man to put in charge of a drill, no matter what his experience may have been.

It is always best to put some one in charge of the drills who has had some experience and knows something of their uses. However, satisfactory drill runners can usually be made by taking bright, intelligent men from the mine and letting them work for a few days with some thoroughly reliable man.

Specifications for a Complete Plant to Operate One of Our Standard $3\frac{5}{16}$ -inch Rock Drills by Compressed Air

- 1 Risdon Improved Air Compressor, complete with improved water circulating jacketed cylinder and heads, automatic sight feed lubricator on both air and steam cylinders, improved unloading device; all oil cups and foundation bolts and washers. Capacity of compressor sufficient to run one of our standard $3\frac{5}{16}$ -inch cylinder rock drills.
- 1 Steel Air Receiver, diameter 30 inches, length 72 inches, furnished complete with manhead, pressure gauge, pop safety valve and blow-off cock.
- 1 Of our standard $3\frac{5}{16}$ -inch cylinder rock drills complete with valves and wrenches (unmounted).
- 1 Improved double screw tunnel column complete with arm, clamp, safety clamp, cups and wrenches.
- 1 Length, (50 ft.,) of 1-inch wire-wound air hose with Risdon improved couplings.
- 1 Set of blacksmith tools for sharpening drill bits, including 1 dolly, $1\frac{1}{4}$ dolly, 1 sow, 1 spreader, 1 flatter, 1 swage.
- 1 Set of fitted steels for drilling holes to a depth of 8 feet, including 6 steels with bits and shanks.
- 1 20 Horse-Power vertical tubular boiler complete with grate bars, bearing bars, smokestack, steam gauge gauge cocks, glass water gauge, safety valve and all fittings, including injector.

Pipe and fittings to connect boiler with compressor and compressor with receiver, including valves and pipes.

Approximate cost of above, depending on style of compressor, \$1500.

Send for discounts.

Specifications for a Complete Plant to Operate Two of Our Standard $3\frac{5}{16}$ -inch Rock Drills by Compressed Air

- 1 Risdon Improved Air Compressor, complete with improved water circulating jacketed cylinder and heads, automatic sight feed lubricator on both air and steam cylinders, improved unloading device; all oil cups and foundation bolts and washers. Capacity of compressor sufficient to run two of our standard $3\frac{5}{16}$ -inch cylinder rock drills.
- 1 Steel Air Receiver, diameter 36 inches, length 72 inches, furnished complete with manhead, pressure gauge, pop safety valve and blow-off cock.
- 2 Of our standard $3\frac{5}{16}$ -inch cylinder rock drills complete with valves and wrenches (unmounted).
- 2 Improved double screw tunnel columns complete with arm, clamp, safety clamp, cups and wrenches.
- 2 Length (50 ft.) of 1-inch wire-wound air hose with Risdon improved couplings.
- 1 Set of blacksmith tools for sharpening drill bits, including 1 dolly, $1\frac{1}{4}$ dolly, 1 sow, 1 spreader, 1 flatter, 1 swage.
- 2 Sets of fitted drill steels for drilling holes to a depth of 8 feet, including 6 steels with bits and shanks.
- 1 30 Horse-Power vertical or horizontal tubular boiler complete with grate bars, bearing bars, smokestack, steam gauge, gauge cocks, glass water gauge, safety valve and all fittings, including injector.

Pipe and fitting to connect boiler with compressor and compressor with receiver, including valves and pipes.

Approximate cost of above, depending on style of compressor, \$2500.

Send for discounts.

Specifications for a Complete Plant to Operate Three of Our Standard $3\frac{5}{16}$ -inch Cylinder Rock Drills by Compressed Air

- 1 Risdon Improved Air Compressor, complete with improved water circulating jacketed cylinder and heads, with automatic sight feed lubricators on both air and steam cylinders, improved unloading device, all oil cups and foundation bolts and washers. Capacity of compressor sufficient to run three of our standard $3\frac{5}{16}$ -inch cylinder rock drills.
- 1 Steel Air Receiver, diameter 36 inches, length 96 inches, furnished complete with manhead, pressure gauge, pop safety valve and blow-off cock.
- 3 Of our standard $3\frac{5}{16}$ -inch cylinder rock drills complete with valves and wrenches (unmounted).
- 3 Improved double screw tunnel columns complete with arms, clamps, safety clamps, cups and wrenches.
- 3 Lengths (50 feet each) of 1-inch wire-wound air hose with Risdon improved couplings.
- 1 Set of blacksmith tools for sharpening drill bits, including 1 dolly, 1 $\frac{1}{4}$ dolly, 1 sow, 1 spreader, 1 flatter, 1 swage.
- 3 Sets of fitted drill steels for drilling holes to a depth of 8 feet (6 steels in set with bits and shanks).
- 1 40 Horse-Power tubular boiler complete with half-arch front, grate bars, bearing bars, steam gauge, glass water gauge, gauge cocks, safety valve, smokestack, and all fittings, including injector.

Pipe and fittings to connect boiler with compressor, and compressor with receiver, including valves and pipes.

Approximate cost of above, depending on style of compressor, \$3500.

Send for discounts.

Specifications for a Complete Plant to Operate Five of Our Standard $3\frac{5}{8}$ -inch Cylinder Rock Drills by Compressed Air

- 1 Improved Air Compressor, with improved water circulating jacketed cylinder, automatic sight feed lubricators on both air and steam cylinders, improved unloading device, Risdon automatic regulator for controlling pressure on steam cylinder, all oil cups and foundation bolts and washers. Capacity of compressor sufficient to run 5 of our standard $3\frac{5}{8}$ -inch cylinder rock drills.
- 1 Steel Air Receiver, diameter 42 inches, length 96 inches, furnished complete with manhead, pressure gauge, pop safety valve and blow-off cock.
- 5 Of our standard 3-inch cylinder rock drills, complete with valves and wrenches (unmounted).
- 5 Improved double screw tunnel columns, complete with arms, clamps, safety clamps, cup and wrenches.
- 5 Lengths (50 feet each) of 1-inch wire-wound air hose with Risdon improved couplings.
- 1 Set of blacksmith tools for sharpening drill bits, including 1 dolly, 1 $\frac{1}{4}$ dolly, 1 sow, 1 spreader, 1 flatter, 1 swage.
- 5 Sets of fitted drill steels for drilling holes to a depth of 8 feet (6 steels in set with bits and shanks).
- 1 80 Horse-Power tubular boiler complete with half-arch front, grate bars, bearing bars, steam gauge, glass water gauge, gauge cocks, safety valve, smokestack, and all fittings, including injector.

Pipe and fittings to connect boiler with compressor, and compressor with receiver, including valves and pipes.

Approximate cost of above, depending on style of compressor, \$6000.

Send for discounts.

LIST

—OF—

Parts of Series G, Size D, Air Drill

	Pieces		Prices
1. Cylinder.....	1	29. Plugs in Front Head.....	4
2. Back Head.....	1	30. Pawl Springs.....	4
3. Front Head	1	31. Inlet and Outlet Plugs.....	4
4. Bonnet.....	1	32. Round Bushing for Head.....	1
5. Shell.....	1	33. Octagon Bushing for Head	1
6. Body of Clamp.....	1	34. Chuck Blocks.....	1
7. Cap for Clamp.....	1	35. U Bolt.....	1
8. Cylinder Extension	1	36. Nuts for U Bolt.....	2
9. Bolts in Clamp.....	2	37. Guide Ring.....	1
10. Washers for Clamp Bolts.....	2	38. Crank Handle for Feed Screw.....	1
11. Nuts for Clamp Bolts.. ..	2	39. Throat Bushing.....	1
12. Piston Rod.....	1	40. Rubber Bumpers for Valves.....	2
13. Front Piston.....	1	41. Guides for Shell	2
14. Back Piston.....	1	42. Bolts for Shell Guides.....	10
15. Key for Front Piston.....	1	43. Struts for Yoke.....	2
16. Key for Back Piston.....	1	44. Yoke	1
17. Front Piston Ring.....	1	45. Bolt for Feed Handle.....	1
18. Back Piston Ring.....	1	46. Wrench for Drill Chuck.....	1
19. Valve.....	1	47. Washer for Rubber Bumper.....	1
20. Buffer Plates.. ..	2	48. Rubber Bumper	1
21. Cylinder Studs.....	6	49. Ring Bolt in Shell.....	1
22. Cylinder Tie Bolts, 2 nuts.....	2	50. Stud Wrench.....	1
23. Feed Screw	1	51. Wrench for Tie Bolts.. ..	1
24. Feed Screw Nut.....	1	52. Key for U Bolt.....	1
25. Bolts for Feed Screw Nut.....	2	53. Oil Plug in Front Head.....	1
26. Guard for Feed Screw	1	54. Pins for Struts in Shell.....	2
27. Ratchet.....	1	55. Nut for King Bolt	1
28. Ratchet Pawls.....	2		

Same Numbers used for "A" Drill.

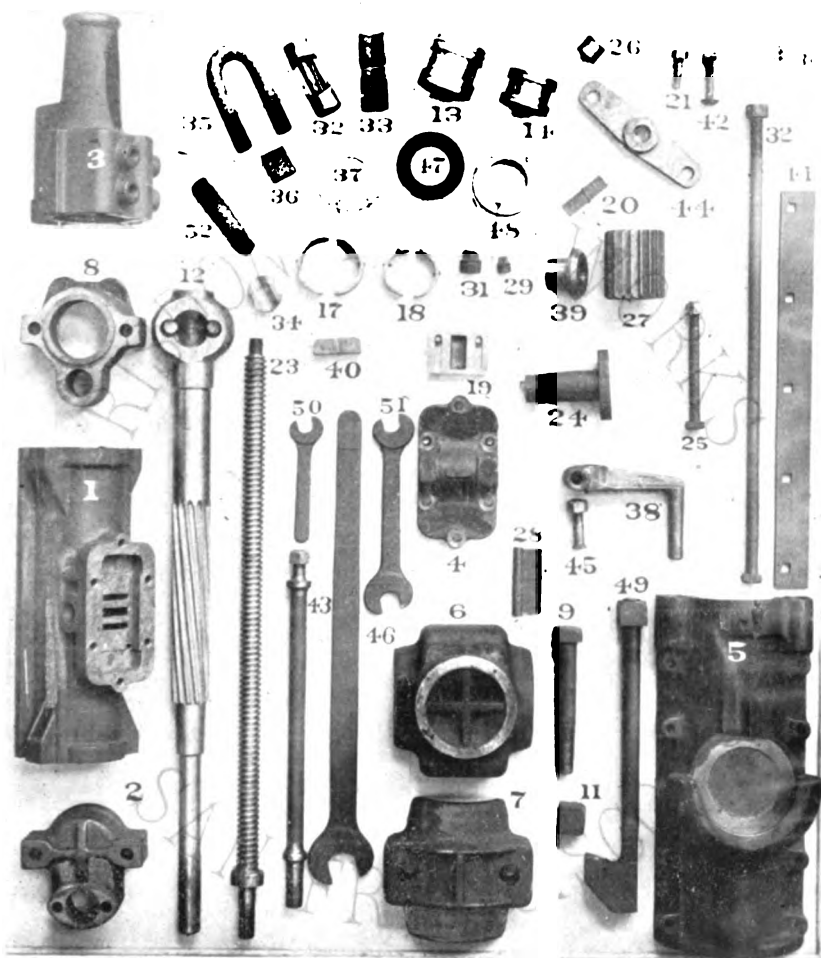


ILLUSTRATION OF PARTS
RISDON DRILLS
 SIZE D., SERIES G.

Same numbers used for "A" drill.

Air Receivers and Pressure Tanks

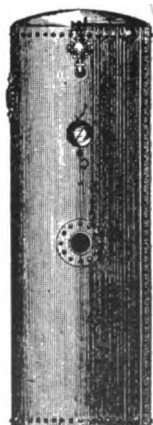
For 110 Pounds Working Pressure

Made of best 60,000 pounds t. s. Steel, side seams double riveted ; strongly made with dished heads, and tested up to 165 pounds water pressure ; warranted safe and tight under 110 pounds working pressure. Fixtures will include manhead, safety valve pressure gauge, drain cocks, and flanges for inlet and discharge pipes.

NO. OF SIZE.	1	2	3	4	5	6	7	8
Diameter inches,	30	36	36	42	42	48	54	66
Length, feet,	6	6	8	8	10	12	12	18
Thickness of Shell . . inches,	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	1	$\frac{1}{4}$	9-32	5-16	$\frac{3}{8}$
Thickness of Heads, . .	5-16	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	7-16	7-16	$\frac{1}{2}$
Weight about lbs.	1000	1300	1600	1900	2200	3300	4200	5500
Diameter of Safety Valve . in.	1½	1½	1½	2	2	2½	2½	3
Diameter of Inlet and Discharge Flanges	2½	3	3½	3½	4	5	6	8
No. of ¾ inch Drills Receiver is best adapted for . .	1	2	3	5	8	12	20	35
Compressor capacity Receiver is best adapted for	150	150	200	300	500	700	1,200	3,000
(cubic feet free air per minute)	or less	to 200	to 300	to 500	to 700	to 1,200	to 3,000	and over

Price, f. o. b. factory complete.

The illustration below shows an air receiver suitable for machine shops, granite yards, and all places where a small air compressor is used. It is made of the best steel, single riveted, tested to 165 pounds water pressure. Warranted safe and tight under 110 pounds working pressure. Fixtures include safety valve pressure gauge, drain cocks, and tap for inlet and discharge pipes.



NO. OF SIZE.		
Diameter, inches,	18	24
Length, feet,	6	6
Thickness of Shell, . . inches,	11-64	3-16
Thickness of Heads, . .	$\frac{1}{4}$	$\frac{1}{4}$
Weight about lbs.	250	350
Diameter or Safety Valve, . in.	1	1½
Diameter of inlet and Discharge, inches,	2½	2½
No. of 2½ inch Drills receiver is best adapted for, . . .	1	2
Compressor capacity receiver is best adapted for (cubic feet free air per minute), . .	90	120

Price, f. o. b. factory complete.

Compressed Air for Rock Drills and Coal Cutters

The following table is intended to show at a glance the *approximate* quantity or volume of free air required for operating Rock Drills and Coal Cutters, the air being delivered to the machines at 60 lbs. pressure.

As applied to Rock Drills, these figures are necessarily approximate only, owing to the varying conditions under which each work is performed; but they will be found to apply closely to average conditions in rock of moderate hardness. A liberal allowance has been made above the actual requirements of new machines, to provide for wear, etc., but of course no allowance is made for leaky pipe, as this should not be permitted to exist. In soft material the actual drilling time is short, and more drills can be run with a given size compressor than where the material is hard and the drills running continuously for a longer period, thereby increasing the chance of all the drills drawing on the compressor at the same time.

In tunnel work in hard rock, where a high air pressure is carried to insure rapid progress, experienced contractors have found it profitable to provide compressor capacity in excess of the usual requirements by 25 to 50 per cent.

As applied to Coal Cutters, the figures given are liberal, and more machines can probably be added where a large plant is in operation; but it should always be remembered that it is better economy to provide a large compressor and run it slowly, rather than a smaller one that has to be driven to its full capacity. This fact is recognized by the best engineers, and it applies more particularly to a compressor than to an engine or boiler.

The capacities in this table are based on *60 pounds air pressure*; if 75 pounds is used, one-fifth more volume should be added; if 90 pounds, two-fifths should be added to the volume stated in the table.

TABLE SHOWING CUBIC FEET OF FREE AIR REQUIRED TO
RUN FROM ONE TO FORTY MACHINES WITH
SIXTY POUNDS PRESSURE

Number of Machines.	ROCK DRILLS		COAL CUTTERS.	
	Size Cylinders		Size Cylinders	
	2 1/4 inch	3 5-16 inch	3 1/4 inch	4 inch
1	65	115	70	93
2	110	200	140	186
3	156	294	210	279
4	196	372	280	372
5	230	445	350	465
6	264	516	420	558
7	294	581	490	651
8	320	640	560	744
9	360	720	630	837
10	400	800	700	930
12	480	960	840	1116
15	.....	1200	1050	1395
20	.....	1600	1400	1860
25	.....	2000	1750	2325
30	.....	2400	2100	2790
40	.....	3200	2800	3720

CAPACITY OF COMPRESSORS

It is a common practice to multiply the area of the air piston by the distance it travels in a minute, and to state the product as the free air capacity of the Compressor. To ascertain the bulk of the air in compressed form, it is necessary to add 15 lbs. to the gauge pressure, and divide the amount by 15. The result will be the number of atmospheres in the air of that pressure. The free air capacity of the Compressor divided by the number of atmospheres will give the amount of air after compression. This amount must be reduced by allowances of various kinds. The losses due to poor designing and workmanship, the use of warm induction air, insufficient supply, losses in clearance and leaks, may be quite serious. In some machines these losses amount to a clear thirty per cent. of their theoretical capacity, whereas ten per cent. should be liberal for all ordinary contingencies. There must, however, be an allowance made in the capacity of all Compressors by reason of their heights above the sea level. At an elevation the air is not so dense as at the sea level, and hence at each revolution the Compressor will take in a less weight of air and be able to do less work. To make exact comparisons of efficiency it is necessary to know whether the compressed air is used expansively or at full stroke, or whether the actual work done is to be compared. Generally speaking, the Compressor will run with less power at the elevation than at the lower level, but its capacity in the amount of compressed air produced will be so much less, that as a net result more power is used to do the same work at a height than at the sea level.

As it is a very common practice to use air in drills and like machines at full stroke, we append a table of efficiencies of Compressors when the air is so used at 60 lbs. per square inch gauge pressure, and at various heights above sea level.

Height in Feet above Sea Level.	Barometer.	Efficiency of Compressor.
0	30 inches	100.0 per cent.
500	29.42 "	98.4 "
1,000	28.85 "	96.9 "
1,500	28.34 "	95.5 "
2,000	27.78 "	94.0 "
3,000	26.74 "	91.1 "
4,000	25.70 "	88.1 "
5,000	24.73 "	85.9 "
6,000	23.83 "	82.8 "
7,000	22.93 "	80.2 "
8,000	22.04 "	77.5 "
9,000	21.22 "	75.1 "
10,000	20.43 "	72.7 "
12,000	18.92 "	68.0 "

Capacity of Air Cylinders for 100 Feet Piston Speed, at 100 Per Cent Volumetric Capacity.

DIAMETER OF CYLINDER.	Free	10 lbs.	20 lbs.	30 lbs.	40 lbs.	50 lbs.	60 lbs.	70 lbs.	80 lbs.	90 lbs.	100 lbs.
	1.00	.595	.423	.329	.268	.227	.196	.173	.155	.140	.127
8 in.	34.91	20.76	14.78	11.48	9.38	7.93	6.86	6.04	5.41	4.89	4.43
10	54.54	32.45	23.10	17.94	14.66	12.39	10.72	9.45	8.46	7.65	6.92
12	78.54	46.73	33.26	25.83	21.11	17.85	15.44	13.61	11.18	11.02	9.97
14	106.92	63.61	45.28	35.17	28.73	24.29	21.02	18.52	16.59	15.00	13.57
16	139.64	83.08	59.14	45.93	37.52	31.73	27.46	24.19	21.66	19.60	17.73
18	176.72	105.14	74.85	58.13	47.49	40.16	34.75	30.62	27.42	24.81	22.44
20	218.16	129.81	92.41	71.77	58.64	49.58	42.91	37.80	33.85	30.62	27.70
24	314.16	186.93	133.07	103.35	84.44	71.40	61.79	54.44	48.75	44.10	39.89
30	490.87	292.08	207.92	161.49	131.94	111.57	96.55	85.06	76.18	68.91	62.34
36	706.88	420.60	299.41	232.55	190.00	160.66	139.03	122.49	109.70	99.24	89.77

Table Showing Cubic Feet of Free Air Compressed and
Delivered Per Minute Per I. H. P., at Various
Gauge Pressures, with Air at 60° Fah.
and at Sea Level.

RECEIVER GAUGE PRESSURE.	Method of Compression.			
	Adiabatic.	Single Stage Jacktd. Cyl.	Double Stage Jacktd. Cyl.	Isothermal.
10	28.0	28.2	28.7	30.3
20	16.0	16.3	16.8	18.2
30	12.0	12.2	12.6	14.1
40	9.8	10.0	10.5	11.9
50	8.5	8.7	9.2	10.5
60	7.5	7.7	8.2	9.6
70	6.8	7.	7.5	8.9
80	6.36	6.6	7.0	8.4
90	5.9	6.2	6.5	8.0
100	5.6	5.8	6.2	7.6
125	4.94	5.1	5.6	6.9
150	4.5	4.7	5.07	6.45

Table Showing I. H. P. Required to Compress and Deliver
100 Cubic Feet of Free Air Per Minute at
Various Pressures, 60° Fah. and
Sea Level.

RECEIVER GAUGE PRESSURE.	Method of Compression.			
	Adiabatic.	Single Stage Jacktd. Cyl.	Double Stage Jacktd. Cyl.	Isothermal.
10	3.57	3.55	3.48	3.3
20	6.22	6.14	5.95	5.5
30	8.33	8.21	7.91	7.1
40	10.21	9.96	9.48	8.4
50	11.73	11.46	10.87	9.5
60	13.25	12.84	12.2	10.4
70	14.67	14.07	13.25	11.2
80	15.72	15.18	14.27	11.9
90	16.88	16.22	15.29	12.6
100	17.83	17.2	16.06	13.2
125	20.21	19.33	18.03	14.4
150	22.31	21.22	19.72	15.5

Loss of Pressure Through Friction of Air in Pipes

For Every 100 Feet Length of Pipe (Initial Gauge Pressure 80 lbs. at Receiver)

Equivalent Volume of Free Air Discharge per minute.	SIZE OF PIPE IN INCHES.													
	1	1 1/4	1 1/2	2	2 1/2	3	4	5	6	7	8	10	12	14
25	.24	.12												
50	1.00	.45	.18											
75	2.4	1.0	.4											
100		1.7	.70	.13										
200			3.00	.50	.175									
300				1.20	.38	.15								
400				2.15	.67	.27								
500				3.30	1.10	.40	.06							
750					2.50	.91	.22	.03	.012	.013				
1000						1.8	.40	.07	.03	.023	.012			
1500						4.00	1.00	.30	.12	.052	.027			
2000							1.60	.50	.20	.095	.048	.017		
3000							3.70	1.20	.45	.22	.115	.036	.015	
4000								2.00	.80	.39	.20	.07	.026	.012
5000									1.30	.60	.30	.10	.041	.018
6000									1.9	.85	.43	.15	.06	.028
7500									3.00	1.40	.68	.22	.09	.04
10000										2.5	1.25	.40	.17	.075

EXAMPLE—An air compressor furnishes 1000 cubic feet of free air per minute at a pressure of 80 pounds per square inch in the receiver. If this air is used at the end of a 4-inch pipe 2000 feet long, the loss due to friction will be 20 x 4 = 8 pounds. If the same volume of air were supplied by the same compressor at the same pressure and passed through a 6-inch pipe 2000 feet long, the loss would be only .05 x 20 = 1 pound; thus illustrating the importance of using pipe of large diameter. Strictly speaking the loss of pressure is not directly proportional to the length; however, for all practical purposes it may be taken as such.

The foregoing table represents the loss by friction in the pipe. There is a further slight loss due to the friction of the air with itself at the mouth of the pipe when it leaves the receiver. Elbows and irregularities in pipe increase the friction above the figures given in the table.

AIR LEAKAGE

All leaks in compressors or valves, air receivers or pipe, should be strictly guarded against for the sake of economy in the running of compressed air and steam apparatus. Air leaks are fully as expensive as steam leaks, and should be as carefully stopped. Too many operators think that an air leak is of but little consequence, but it should never be allowed, save where needed for actual ventilation.

TABLE FOR BRANCH PIPES

IT IS A COMMON IDEA that the carrying capacity of a pipe is in proportion to its internal area. This is, however, not correct. A pipe four feet in diameter has only four times the area of a pipe two feet in diameter, and yet the four feet pipe will carry 5.66 times as much fluid as the two feet pipe, under the same conditions of length and head. In other words a two feet pipe will carry 17.6 per cent. or nearly 18 per cent. as much as will a four feet pipe. This proportion of carrying capacity does not hold good for smaller pipes of the same proportionate diameter. A one foot pipe has only 16.6 per cent. of the carrying capacity of a pipe two feet in diameter, and a one inch pipe will carry only 14 per cent. as much as a 2 inch pipe.

THESE FEATURES have not to our knowledge been heretofore taken into consideration in tables prepared for equalizing pipes. The proper values are given in the table below. In this table the commercial or nominal size is given, but in our calculations we figured $1\frac{1}{4}$ inch pipe as 1.3 inches diameter, and $1\frac{1}{2}$ inch pipe at 1.6 inches, as these are nearer the actual sizes.

THE SIZE OF PIPE is given in the horizontal line on top, and directly beneath is stated successively the proportion of its capacity that other pipes will carry. These other pipes are stated in the vertical column on the left.

For example a six inch pipe can have 15 per cent. of its capacity carried by a 3 inch pipe, 23 per cent. by a $3\frac{1}{2}$ inch pipe, 34 per cent. by a 4 inch pipe, and a 24 inch pipe will carry 38 times as much as the 6 inch pipe.

IN TAKING BRANCHES from a main it is advisable that the sum of the percentages of the carrying capacities of the branches should be 100 per cent. or more. Referring again to a 6 inch main we see that if it be divided into two branches, one 4 inches and the other 5 inches, the carrying capacities of the branches would be respectively 34 and 63 per cent. of the 6 inch pipe. Thus provision is made for only 97 per cent. and there would be slight additional friction from the point of diversion of the branches. If the branches be made $4\frac{1}{2}$ and 5 inches, the percentages are respectively 47 and 63, their sum 110 and, from the junction, the flow would be considerably more free than in the first case.

RELATIVE CARRYING CAPACITY OF PIPES FOR AIR.

	1	1 $\frac{1}{4}$	1 $\frac{1}{2}$	2	2 $\frac{1}{2}$	3	3 $\frac{1}{2}$	4	4 $\frac{1}{2}$	5	6	7	8	10	12	24
1	1.	.48	.27	.14	.07	.05										
1 $\frac{1}{4}$	2.1	1.	.55	.29	.16	.10	.06									
1 $\frac{1}{2}$	3.7	1.8	1.	.53	.29	.18	.11	.08								
2	7.14	3.4	1.9	1.	.53	.33	.21	.14	.10							
2 $\frac{1}{2}$	13.4	6.3	3.5	1.9	1.	.63	.40	.27	.20	.15						
3	21.4	10.3	5.7	3.	1.6	1.	.67	.43	.32	.23	.15					
3 $\frac{1}{2}$		16.1	9.	4.7	2.5	1.5	1.	.68	.50	.38	.23	.15				
4			13.1	6.9	3.7	2.3	1.4	1.	.71	.56	.34	.23	.15			
4 $\frac{1}{2}$				9.6	5.	3.1	2.	1.4	1.	.77	.47	.31	.21	.12		
5					6.7	4.4	2.6	1.8	1.3	1.	.63	.42	.28	.16	.10	
6						6.5	4.3	2.9	2.1	1.6	1.	.66	.45	.26	.16	.03
7							6.5	4.4	3.2	2.4	1.5	1.	.71	.40	.24	.04
8								6.5	4.7	3.5	2.2	1.4	1.	.59	.36	.06
10									8.3	6.3	3.9	2.5	1.7	1.	.61	.10
12										10.3	6.3	4.1	2.8	1.6	1.	.17
24											38.	24.	17.3	9.6	6.	1.

Pumps Driven by Compressed Air

Height of Water Column in Feet.		50	75	100	125	150	175	200	250	300	350	400	450	500
Relative Proportion of Areas of the Cylinders of the Pump.	to 2	25. .40	37. .51	50. .65	62. .77	75. .90	87. 1.03							
	2 to 1		18. .66	25. .80	31. .92	38. 1.06	43. 1.15	50. 1.30	62. 1.54	75. 1.80	87. 2.04			
	2½ to 1		15. .75	20. .8	25. .99	30. 1.13	35. 1.25	40. 1.37	50. 1.62	60. 1.87	70. 2.14	80. 2.38		
	3 to 1			17. .95	21. 1.07	25. 1.19	29. 1.32	33. 1.45	42. 1.68	50. 1.95	58. 2.20	67. 2.44	75. 2.70	81. 2.92
	3½ to 1			14. 1.02	18. 1.14	21. 1.37	25. 1.39	29. 1.52	36. 1.76	43. 2.03	50. 2.28	57. 2.51	64. 2.75	71. 3.00
	4 to 1				15. 1.22	19. 1.34	22. 1.46	25. 1.58	31. 1.84	37. 2.09	44. 2.35	50. 2.59	56. 2.83	62. 3.08
	5 to 1					15. 1.49	18. 1.60	20. 1.76	25. 1.98	30. 2.27	35. 2.51	40. 2.73	45. 3.02	50. 3.24

Compressed air is largely used for driving Direct Acting Pumps in mines and at points distant from the power. In many cases these pumps are at first driven by steam, but as the work advances and the pump is moved forward, steam becomes powerless and also develops troublesome and unpleasant characteristics.

Compressed air does not condense ; its exhaust is cool and the resulting ventilation most agreeable.

Any steam pump can readily be driven by air. It will move a little quicker under air than with steam of the same pressure, as the valve movements are not delayed by water of condensation.

For the reason that dry air will escape through an opening faster than wet steam which is loaded with water, it is advisable to see that the pump pistons and valves are in good condition when a change is made from steam to air power.

The above table gives the particulars relating to Pumps driven by air. The stated air pressure is the pressure in the pump driving the cylinder.

The proportion of cylinders is obtained by dividing the area of the air or driving cylinder by the area of the water cylinder.

A pump having an 8-inch air or steam cylinder and a 5-inch water cylinder is proportioned 2½ to 1. Such a pump, when raising water 175 feet through a short pipe of liberal area, will use 1.25 cubic feet of free air for each gallon of water pumped.

The easy capacity of this pump is 80 gallons per minute, and at that speed it would use 100 cubic feet of free air. This air must be delivered into the driving cylinders at 35 lbs. gauge measure.

Reasonable allowance has been made in the table for friction and clearance.

The throttle valve on the pump will control the air pressure, but it is advisable to proportion pumps as far as possible so that the air pressure needed in them is nearly equal to the pressure in the air mains near by. Pumps that move with very light pressure use more air for the same work.

For example, a gallon of water raised 175 feet by a 5 to 1 pump needs 1.6 cubic feet of air, whereas if the pump were 2 to 1, the air needed is only 1.15 cubic feet,—a saving of 28 per cent. in quantity of air. This is worth the consideration of parties who find their Compressors are becoming too small for their work. This point is also commended to the attention of those who think the pump takes little air, because "you only need to just lift the throttle off its seat the merest trifle."

On the opposite page we have not considered the question of reheating, and here give a table showing the percentage required for the different kinds of power-actuated pumps, both for cold air and air reheated to 300 degrees Fah. at the pump engine.

Kind Engine.	Cold Air 60° Fah.	Reheated Air 300° Fah.
Direct Acting Single.....	1.	.69
Direct Acting Compound.....	70	.48
Crank and Fly Wheel Slide Valve.....	60	.41
Crank and Fly Wheel Slide Valve Compound.....	50	.33
Corliss Compound.....	33	.23

Pump Table for Large Pumping Plants

For the convenience of engineers and others figuring on large pumping plants, to be operated by compressed air, we subjoin another table by which the pressure and volume of air required for any size pump can be readily ascertained. Reasonable allowances have been made for loss due to clearances in pump and friction in pipe.

Ratio of Diameters.		PERPENDICULAR HEIGHT, IN FEET, TO WHICH THE WATER IS TO BE PUMPED.															Air Pressure at Pump.	Cubic Feet of Free Air Per Gallon of Water.
		25	50	75	100	125	150	175	200	225	250	300	350	400	450	500	Air Pressure at Pump.	Cubic Feet of Free Air Per Gallon of Water.
1	to 1	13.75	27.5	41.25	55.0	68.25	82.5	96.25	110.0									
		0.21	0.45	0.60	0.75	0.89	1.04	1.20	1.34									
1½	to 1	12.22	18.33	24.44	30.33	36.66	42.76	48.88	55.0	61.11	73.32	85.4	97.66					
		0.65	0.80	0.95	1.09	1.24	1.39	1.53	1.68	1.83	2.12	2.41	2.70					
1¾	to 1		13.75	19.8	22.8	27.5	32.1	36.66	41.25	45.83	55.0	64.16	73.33	82.5				
			0.94	1.14	1.24	1.30	1.54	1.69	1.84	1.99	2.39	2.59	2.83	3.19				
2	to 1			13.75	17.19	20.63	24.06	27.5	30.94	34.38	41.25	48.13	55.0	61.88	68.75			
				1.23	1.37	1.52	1.66	1.81	1.96	2.11	2.40	2.69	2.98	3.28	3.57			
2¼	to 1				13.75	16.5	19.25	22.0	24.75	27.5	33.0	38.5	44.0	49.5	55.0			
					1.533	1.68	1.83	1.97	2.12	2.26	2.56	2.85	3.15	3.44	3.73			
2½	to 1					13.2	15.4	17.6	19.8	22.0	26.4	30.8	35.2	39.6	44.0			
						1.79	1.96	2.06	2.104	2.34	2.62	2.88	3.18	3.36	3.23			

To find the amount of air and pressure required to pump a given quantity of water a given height, find the ratio of diameters between water and air cylinders, and multiply the number of gallons of water by the figure found in the column for the required lift. The result is the number of cubic feet of free air. The pressure required on the pump will be found directly above in the same column. For example: The ratio between cylinders being 2 to 1. Required to pump 100 gallons, height of lift 250 feet. We find under 250 feet at ratio 2 to 1, the figures 2.11; 2.11 x 100 = 211 cubic feet of free air. The pressure required is 34.38 pounds.

COMPRESSED AIR FOR HOISTING ENGINES

The following table is intended to give an approximate idea of the volume of free air required for operating hoisting engines, the air being delivered to the engines at 60 lbs. gauge pressure. There are so many variable conditions to the operation of hoisting by the hoisting engines in common use that accurate computations can only be offered when fixed data are given. In the table, the hoisting engine is assumed to actually run but one half of the time for hoisting, while the compressor, of course, runs continuously. If the engine runs less than one-half the time, as it usually does, the volume of air required will be proportionately less, and *vice versa*. The table is computed for maximum loads, which also in practice may vary widely. From the intermittent character of the work of a hoisting engine the parts are able to resume their normal temperature between the hoists, and there is little probability of the annoyance of freezing up the exhaust passages.

Table of the Volume of Free Air Required for Operating Hoisting Engines, the Air Compressed to 60 Pounds Gauge Pressure

SINGLE CYLINDER HOISTING ENGINE.							DOUBLE CYLINDER HOISTING ENGINE.						
Diam. of Cylinder Inches.	Stroke. Inches.	Revolu- tions per Minute.	Normal Horse Power.	Actual Horse Power.	Weight Lifted, Single Rope.	Cubic ft. of Free Air Re- quired.	Diam. of Cylinder Inches.	Stroke. Inches.	Revolu- tions per Minute.	Normal Horse Power.	Actual Horse Power.	Weight Lifted, Single Rope.	Cubic ft. of Free Air Re- quired.
5	6	250	3	5.9	600	75	5	6	200	6	11.8	1,000	150
5	8	160	4	6.3	1,000	80	5	8	160	8	12.6	1,650	160
6½	8	160	6	9.9	1,500	125	6½	8	160	12	19.8	2,500	250
7	10	125	10	12.1	2,000	151	7	10	125	20	24.2	3,500	302
8½	10	125	15	16.8	3,000	170	8½	10	125	30	33.6	6,000	340
8½	12	110	20	18.9	5,000	238	8½	12	110	40	37.8	8,000	476
10	12	110	25	26.2	6,000	330	10	12	110	50	52.4	10,000	660
12	14	100	40	45.	.....	560	12	14	100	75	89.2	.....	1,125
14	18	90	50	65	.....	750	14	18	100	100	125	.....	1,587

Compound Corliss Hoisting Engines

Size	Cylinders.		Cubic Feet Free Air.	Brake H. P.
	H. P.	L. P. Strokes.		
10	14	30	665	75
12	18	30	1300	150
14	20	30	1600	200
14	20	36	2000	225

Initial Pressure, 70 pounds.

Intermediate Pressure, 23 pounds.

Final Pressure, 2 pounds.

Initial Temperature, 300 degrees Fah.

Final Temperature, 170 degrees Fah.

Cut off 55° of stroke.

Air before reheating, 60° Fah.



RISDON AIR REHEATER

The accompanying cut represents Air Reheater in its simplest and most efficient form, the heater proper being made of two cast-iron shells, bolted together, having no tubes of any description to burn out or leak.

The heater is made in one size only, the extreme dimensions being 42 inches diameter by 54 inches high, the grate being 19 inches in diameter.

From tests made with this heater it has been found capable of heating 340 cubic feet of free air per minute at forty lbs. pressure to 360° F., giving a gain of 35 per cent. in the measured amount of the work done by the air after passing through the heater, compared with the same volume of air when used cold.

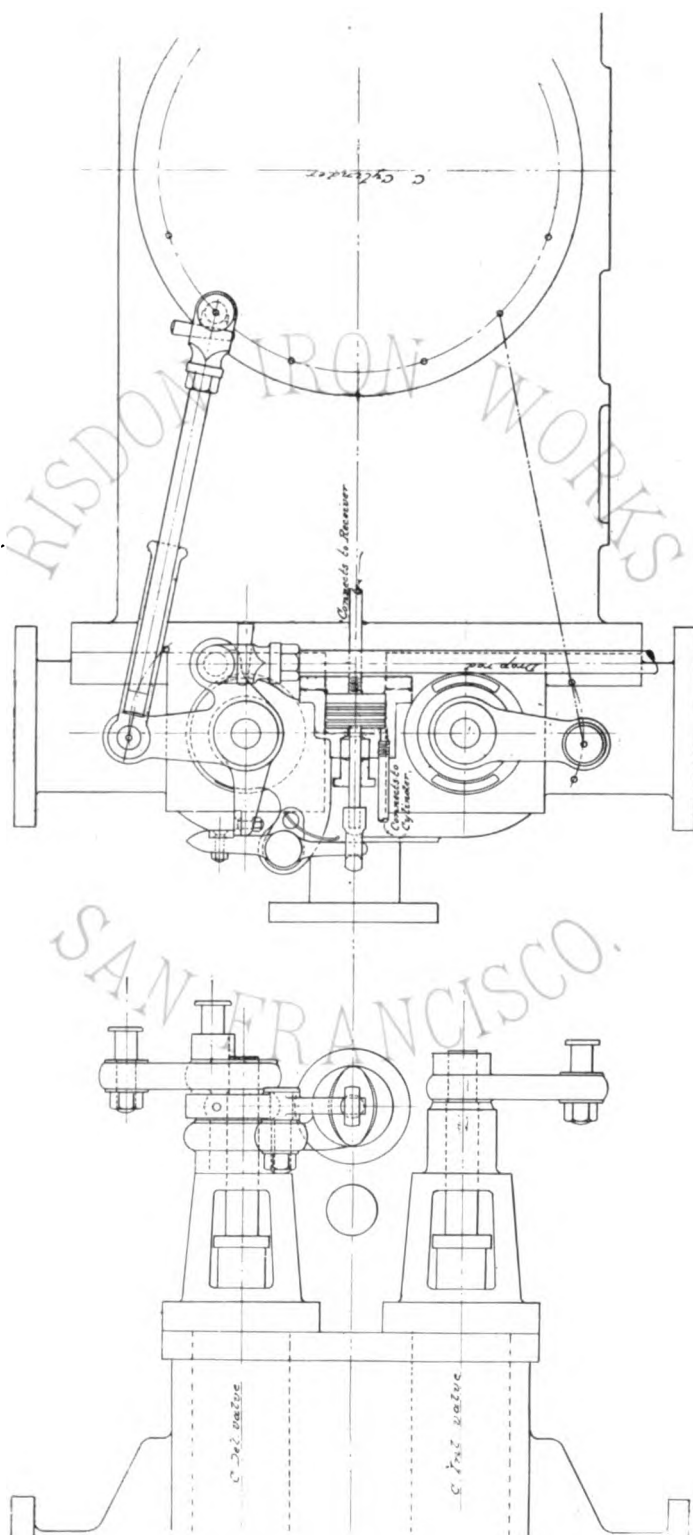
A heater of this size will heat less air to a higher temperature, or more air to a lower temperature, than stated above; but, if it should be required to heat more than 400 cubic feet of free air per minute, to get the best economy, it is advisable to use the heaters in series, allowing about 400 cubic feet of free air per minute for each heater. The heater should be placed as near as possible to the point where the air is to be used, and the outlet pipe should be as short as possible and well covered, so that the air will retain its heat. Weight, 2,300 lbs.

Risdon Blowing Engines

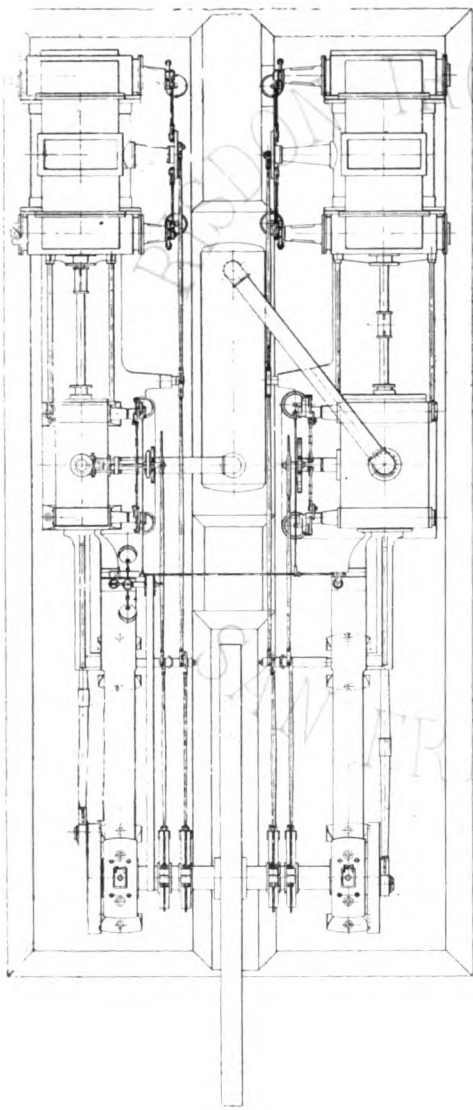
On pages 78 and 79 we illustrate our Blowing Engines and are prepared to build both Horizontal and Vertical, Corliss or Poppet Valves on Steam Cylinders and our improved Corliss Air Inlet and Discharge Valves on Air Cylinder. See page 77.

We build simple compound or triple expansion engines for any duty.

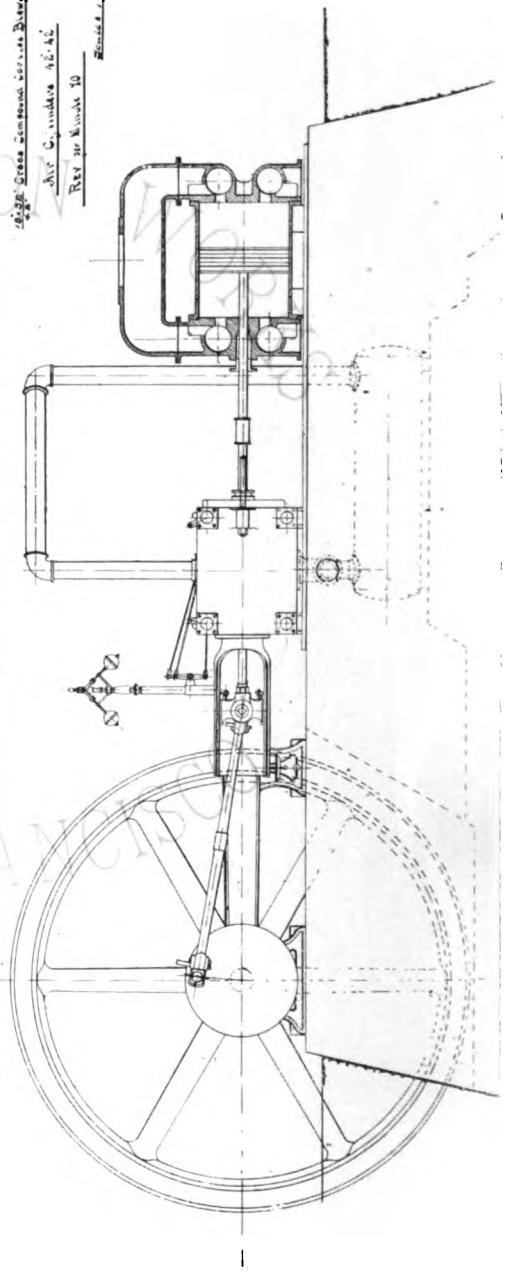
*Detail of Valve Gear in
Baker's Corliss Compressor
Scale 1/2"*



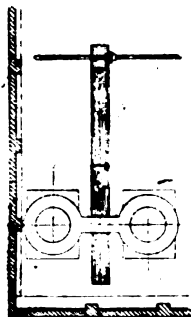
Valve Gear on our Corliss Valve Blowing Cylinders



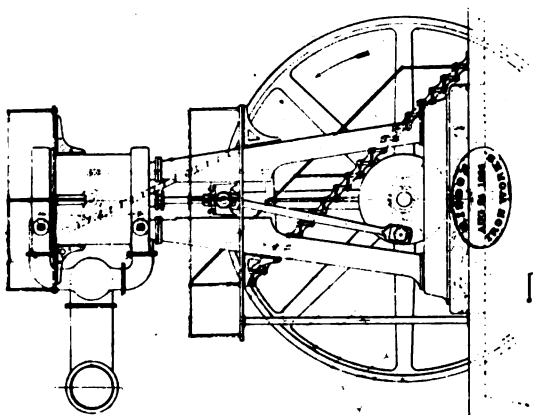
1898. Green with Brown. Patent. Green.
 Air Condenser 12.42
 Box for Valve 10
 1898. 10



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**WATER POWER VERTICAL
BLOWING ENGINE**
Cylinders 2-1/2" to 30" H.P.
1,000 C.U.F.T. Free Air
to
3,000 C.U.F.T. Free Air
Designed by
R. L. WOOD, IRON WORKS, WOODS



USEFUL COMPRESSED-AIR FORMULÆ

In the application of compressed air, errors sometimes occur because there are no available rules and formulæ which apply to the subject. I have, therefore, prepared the following simple formulæ, which I have used in my experience.

Rule to Describe the Isothermal Curve, or to Find the Pressure at Any Point in the Stroke of an Air Compressor During Isothermal Compression or Constant Temperature

Mariotte's Law: The pressure of any gas varies in the inverse ratio of the volume, the temperature remaining constant, or

$$(a) \quad P' = \frac{P}{V}$$

P' being the absolute pressure at any point of the stroke;

P the original absolute pressure;

V the volume corresponding to the required point of the stroke.

Required the pressure at one-half the stroke, compressing isothermally:

$$P' = \frac{15}{\frac{1}{2}} = 30 \text{ lbs. absolute} - 15 = 15 \text{ lbs. gauge pressure.}$$

Required the pressure at seven-eighths of the stroke:

$$P' = \frac{15}{\frac{1}{8}} = 120 \text{ lbs. absolute} - 15 = 105 \text{ lbs. gauge pressure.}$$

Required the pressure at one-quarter of the stroke:

$$P' = \frac{15}{\frac{3}{4}} = 20 \text{ lbs. absolute} - 15 = 5 \text{ lbs. pressure.}$$

Mariotte's law also applies in determining change of pressure in volumes of compressed air due to change of volume.

Given a volume of air, say 1 cu. ft., at a pressure of 30 lbs. on the gauge, what will be the pressure indicated if this air is forced into one-half the space?

$$(b) \quad P' = \frac{1 \times (30 + 15)}{\frac{1}{2}} = 90 \text{ lbs. absolute} - 15 = 75 \text{ lbs. gauge pressure.}$$

Reversing the Problem. Given a volume of air, say 1 cu. ft., at a pressure of 75 lbs. on the gauge, what will be the pressure indicated if this air is expanded to 2 cu. ft.?

$$P' = \frac{1 \times (75 + 15)}{2} = 45 \text{ lbs. absolute} - 15 = 30 \text{ lbs. gauge pressure.}$$

Example. A receiver 3 ft. in diameter and 6 ft. long is filled with compressed air which indicates 60 lbs. on the gauge. What will be the pressure if this volume of air is enclosed in a receiver 4 ft. in diameter and 12 ft. long?

Volume of first receiver = $3^2 \times .7854 \times 6 = 42.4 \text{ cu. ft.}$

Volume of second receiver = $4^2 \times .7854 \times 12 = 150.8 \text{ cu. ft.}$

$$P' = \frac{42.4 \times (60 + 15)}{150.8} = 21.1 \text{ lbs. absolute} - 15 = 6.1 \text{ lbs. gauge pressure.}$$

The same rule applies in calculating volumes. In dealing practically with compressed air, we speak of pressure above the atmosphere, but in making calculations for volumes, serious errors frequently occur because the atmospheric pressure (15 lbs.) is lost sight of.

For instance, a cubic foot of air represents about 15 pounds absolute pressure, and if we wish to know what volume this cubic foot will occupy when it is subjected to a pressure (isothermally) of 60 pounds per square inch above the atmosphere, we must figure thus :

$$(c) \quad V = \frac{1 \times 15}{60 + 15} = 0.20 \text{ cu. ft.}$$

Given 1 cu. ft. of compressed air, at 45 lbs. gauge pressure, what volume will this air occupy when subjected to a gauge pressure of 60 lbs.?

$$(d) \quad V = \frac{1 \times (45 + 15)}{60 + 15} = 0.8 \text{ cu. ft.}$$

Free Air. By free air is meant air at atmospheric pressure, which is about 15 lbs. per square inch at sea-level.

Given a volume, say 500 ft. of free air, what volume will this air occupy when compressed (isothermally) to 60 lbs. gauge pressure?

$$V' = \frac{500 \times 15}{60 + 15} = 100 \text{ cu. ft.}$$

Reversing the Problem. How much free air is represented by 100 cu. ft. of compressed air at 60 lbs. gauge pressure?

$$V' = \frac{100 \times (60 + 15)}{15} = 500 \text{ cu. ft.}$$

Volumes of Free and Compressed Air Furnished by Air Compressors.

Example. The air cylinder of a compressor is 12 inches in diameter, stroke 18 inches. What volume of free air will it furnish (theoretical) when running at 120 revolutions per minute? 120 revolutions represent 360 ft. piston speed per minute.

$$12^2 \times .7854 = 113.1 \text{ area in square inches}$$

$$\frac{113.1 \times 360}{144} = 282.7 \text{ cu. ft. free air.}$$

$$\text{And by (c)} \quad \frac{282.7 \times 15}{60 + 15} = 56.5 \text{ cu. ft. of compressed air at 60 lbs. on gauge.}$$

A rule by which volumes of compressed air may be approximately determined from volumes of free air is to divide by the number of atmospheres.

For instance, 60 lbs. represents 5 atmospheres (absolute); 500 cu. ft. of free air, divided by 5, equals 100 cu. ft. of compressed air at 60 lbs. gauge pressure.

As pressures are not always given in even multiples of atmospheres, this rule serves only to determine approximate results.

Reduced Efficiency of Air Compressors at Different Altitudes

The previous figures are based on the pressure of air at sea-level, or 15 lbs. (about) per square inch. As air compressors are frequently used at altitudes, it is

desirable to know the extent to which an increased altitude affects the capacity of the compressor. Following are the barometric pressures at different altitudes :

Pressure at	$\frac{1}{4}$ mile above sea level	.....	14.02 lbs. per sq. in.		
"	$\frac{1}{2}$ " " "	.....	13.33 " " "		
"	$\frac{3}{4}$ " " "	.....	12.66 " " "		
"	1 " " "	.....	12.02 " " "		
"	$1\frac{1}{4}$ " " "	.....	11.42 " " "		
"	$1\frac{1}{2}$ " " "	.....	10.88 " " "		
"	2 " " "	.....	9.88 " " "		

Free air as applied to the volume of a compressor, or the space traversed by the piston, is not affected by change of altitude, but free air when applied to pressures, either absolute or indicated, and to volumes of compressed air, is modified according to the density of the air at corresponding points.

Example. Required the volume in feet of cubic comprsseed air furnished by an air compressor when at work one mile above sea level. Also, the volume in cubic feet of free air representing the reduced efficiency of the compressor when at work at this altitude.

Given an air compressor of the following dimensions: Diameter 12 inches, stroke 18 inches, revolutions per minute, 120.

We have seen by a previous example that this compressor furnishes 282.7 cu. ft. of free air (theoretical) at sea level, and that this volume represents 56.5 cu. ft. of compressed air at 60 lbs. on the gauge. If this compressor is used at an altitude of one mile above the sea, what volume of compressed air will it furnish at 60 lbs. on the gauge, the speed remaining the same.

Free air furnished by compressor, 282.7 cubic feet.

Barometric pressure at altitudes of one mile, 12.02 lbs., then by (c) substituting the reduced barometric pressure we have

$$V' = \frac{282.7 \times 12.02}{60 + 12.02} = 47.18 \text{ cu. ft. at 60 lbs. on gauge.}$$

And if it is desired to know how many cubic feet of free air at sea-level are represented by 47.18 cu. ft. of compressed air at 60 lbs., we have by

$$(d) \quad V' = \frac{47.18 \times (60 + 15)}{15} = 235.9 \text{ cu. ft. of free air at sea-level,}$$

and $282.7 - 235.9 = 46.8$ cu. ft. of free air, representing the reduced efficiency of the compressor when used at an altitude of one mile.

In practice, approximate determinations of the reduced efficiency of air compressors are made by deducting the percentage of difference between the barometric pressures at the respective altitudes.

The volume at sea-level being 1,

that at	$\frac{1}{4}$ mile above sea-level	will be	.....	7% less.
"	$\frac{1}{2}$ " " "	" " "	.....	11% "
"	$\frac{3}{4}$ " " "	" " "	.....	16% "
"	1 " " "	" " "	.....	20% "
"	$1\frac{1}{4}$ " " "	" " "	.....	24% "
"	$1\frac{1}{2}$ " " "	" " "	.....	28% "
"	2 " " "	" " "	.....	34% "

THE EFFICIENCY OF COMPRESSED AIR ENGINES

BY A PROMINENT PNEUMATIC ENGINEER.

(Republished.)

THE INCREASING USE which is being made of compressed air engines, for mine and underground work, stimulates the inquiry regarding their efficiency. By the term efficiency, we mean the percentage which the power given out by the Air Engine bears to the power required to compress the air in the Compressor.

THE SITUATION is apparently very simple. An engine drives an Air Compressor which forces air into a Reservoir. The air under pressure is led through pipes to the Air Engine and is there used after the manner of steam.

THE RESULTING POWER is frequently a small percentage of the power expended. In a large number of cases the losses are due to poor designing, and are not chargeable as faults of the system or even to poor workmanship.

THE LOSSES are chargeable, first, to friction of the Compressor. This will amount ordinarily to 15 or 20 per cent., and can be helped by good workmanship, but cannot probably be reduced below 10 per cent. Second, we have the loss occasioned by pumping the air of the engine room, rather than the air drawn from a cooler place. This loss varies with the season and amounts from 3 to 10 per cent. This can all be saved. The third loss, or series of losses, arises in the compressing cylinder. Insufficient supply, difficult discharge, defective cooling arrangements, poor lubrication, and a host of other causes, perplex the designer and rob the owner of power. The fourth loss is found in the pipe. This has heretofore received by no means the consideration which the subject demands. The loss varies with every different situation, and is subject to somewhat complex influences. The fifth loss is chargeable to fall of temperature in the cylinder of the air engine. Losses arising from leaks are often serious, but the remedy is too evident to require demonstration. No leak can be too small to require immediate attention. An attendant who is careless about packings and hose couplings will permit losses for which no amount of engineering skill can compensate.

WE CAN ONLY REALIZE 100 PER CENT. EFFICIENCY in the Air Engine, leaving friction out of our consideration, when the expansion of the air and the changes of its temperature in the expanding or Air Engine cylinder are precisely the reverse of the changes which have taken place during the compression of the air in the compressing cylinder. But these conditions can never be realized. The air during compression becomes heated, and during expansion it becomes cold. If the air immediately after compression, before the loss of any heat, were used in an Air Engine and there perfectly expanded back to atmospheric pressure, it would on being exhausted have the same temperature it had before compression and its efficiency would be 100 per cent.

BUT THE LOSS OF HEAT after compression and before use cannot be prevented, as the air is exposed to such very large radiating surfaces in the Reservoir and Pipes, on its passage to the Air Engine. The heat, which escapes in this way, did, while in the compressing cylinder, add much to the resistance of the air to compression, and since it is sure to escape at some time, either in Reservoir or Pipes, it is evidently the best plan to remove it as fast as possible from the cylinder and thus remove one element of resistance. Hence we find that Compressors are almost universally provided with cooling attachments more or less perfect in their action, the aim being to secure isothermal compression, or compression having equal temperature throughout. Where the temperature rises, without check, during compression, the term adiabatic compression is employed.

IF AIR COMPRESSED ISOTHERMALLY be used with perfect expansion and the fall of temperature during expansion be prevented, then we will have 100 per cent. efficiency. But air will grow cold on being expanded in an engine and hence we conclude that warming attachments have the same economic place on an air engine, that cooling attachments have on an Air Compressor. In fact we find attachments of this kind, more particularly in large and permanently located engines, but for practical reasons their use on the most of engines for mine work is dispensed with, and the engines expand the air adiabatically, or without receiving heat.

THE PRACTICAL ENGINEER therefore has to deal with nearly isothermal compression, and nearly adiabatic expansion, and must also consider that the air in Reservoirs and Pipes becomes of the same temperature as surrounding objects. Consideration must also be had for the friction of the Compressor and the Air Engine. We find for the ordinary pressures, about 60 pounds, which are most commonly used, that the decrease in resistance to compression which is secured by the cooling attachments, is almost exactly equaled by the friction of the Compressor. Hence it is safe in calculating the efficiency of the Air Engine, to consider the Compressor as being without cooling attachments and also as working without friction. The results of such calculations will be too high efficiencies for light pressures, which are little used,—about correct for medium pressures which are commonly employed, and too low for high pressures, and will thus have the advantage of not being over-estimated. This result is

occasioned by the fact that owing to the slight heat in compressing low pressures of air the saving of power by the cooling attachments is not equal to the friction of the machine, but at high pressures on account of the great heat, the cooling attachments are of great value, and save very much more power than friction consumes.

IN THE EXPANDING ENGINES the expansion never falls as low as the adiabatic law would indicate, owing to a number of reasons, but we will consider the expansion as being adiabatic, as an error in calculation caused thereby will be on the "safe side" and the actual power will exceed the calculated. We therefore consider the Compressor and Engine as following the adiabatic law of compression and expansion and as working without friction.

WITH THIS VIEW OF THE CASE, the efficiency of an air engine, working with perfect expansion, stated in percentages of the power required to operate the Compressor, can be placed as below for the various pressures above the atmosphere.*

Pressure above the atmosphere,	2.9 lbs.	94.85 per cent. efficiency.
" " " "	14.7 "	81.79 " "
" " " "	29.4 "	72.72 " "
" " " "	44.1 "	66.90 " "
" " " "	58.8 "	62.70 " "
" " " "	73.5 "	59.48 " "
" " " "	88.2 "	56.88 " "

WE OBSERVE that the efficiencies for the lower pressures are very much greater than for the high pressures, and the conclusion is almost irresistible that to secure economical results, we must design our air engines to run with light pressures. And, in fact, the consideration of tables similar to the above, heretofore published by writers on this subject, has led many engineers into grave errors.

THE PIPE HAS BEEN ENTIRELY NEGLECTED. We notice that a pressure of 2.9 lbs. is credited with an efficiency of 94.85 per cent. It is clear that if the air were conveyed through a pipe, and the length of the pipe and the velocity of the flow were such that 2.9 lbs. pressure were lost in friction, then its efficiency instead of being 94.85 per cent. would be absolutely zero. It is therefore the power which we can get from the air after it has passed the pipe and lost a part of its pressure by friction that we must consider when we state the efficiency of our entire apparatus.

*In the above table, and in the tables hereafter given in this article, the air is considered as being expanded without receiving any heat. Larger returns can be had by heating the air.

OUR TABLE OF EFFICIENCIES with a loss of 2.9 lbs. in the pipe, now gives us different values for the efficiencies at the various pressures :

Pressure above the atmosphere,				2.9 lbs.	00.00 per cent. efficiency.		
"	"	"	"	14.7 "	70.44	"	"
"	"	"	"	29.4 "	68.81	"	"
"	"	"	"	44.1 "	64.87	"	"
"	"	"	"	58.8 "	61.48	"	"
"	"	"	"	73.5 "	58.62	"	"
"	"	"	"	88.2 "	66.23	"	"

It will be noticed that the light pressures have lost most by the pipe friction; 2.9 lbs. having lost 100 per cent.; 14.7 lbs. 11 per cent., and 88.2 lbs. only a trifle over one-half of one per cent. We see that now 14.7 lbs. is apparently the economical pressure to use. But a further careful analysis of the subject shows that when the loss in the pipe is 2.9 lbs., then 20.5 lbs. is the most economical pressure to use and that the efficiency is 71 per cent. But 2.9 lbs. is a very small loss between Compressor and Air Engine, and cases are extremely exceptional where the friction of valves, pipes, elbows, ports, etc., does not far exceed this. Yet, with these conditions, which are very difficult to fill, we see that 20.5 lbs. is the lightest pressure which should probably be used for conveying power, and that 71 per cent. is an efficiency scarcely to be obtained, unless reheating the air is practiced.

CONTINUING OUR INVESTIGATION and taking examples where the pipe friction amounts to 5.8lbs., we find the efficiencies to correspond to the stated pressure :

Pressure above the atmosphere,				14.7 lbs.	57.14 per cent. efficiency.		
"	"	"	"	29.4 "	64.49	"	"
"	"	"	"	44.1 "	62.71	"	"
"	"	"	"	58.8 "	60.12	"	"
"	"	"	"	73.5 "	57.73	"	"
"	"	"	"	88.2 "	56.59	"	"

We again notice that as friction increases, or in other words, when we begin to use more air and make greater demands on the carrying capacity of the pipe, then we must increase the pressure very considerably to attain the most economical results. If the demands are such as to increase the friction and loss in pipe to 14.7 lbs., the air of 14.7 lbs. pressure at the Compressor is entirely useless at the Air Engine.

The table will stand thus :

Pressure above the atmosphere,	14.7 lbs.	00.00 per cent. efficiency.
" " " "	29.4 "	48.53 " "
" " " "	44.1 "	55.13 " "
" " " "	58.8 "	55.64 " "
" " " "	73.5 "	54.74 " "
" " " "	88.2 "	53.44 " "

It is to be noticed that 88.2 lbs. pressure has lost only about 3.5 per cent. of its efficiency by reason of as high a friction as 14.7 lbs. while the efficiency of the lower pressures has been greatly affected.

AS THE FRICTION INCREASES we see that the most efficient and consequently most economical pressure increases. In fact, for any given friction in a pipe, the pressure at the Compressor must not be carried below a certain limit. The following table gives the *lowest pressures* which should be used at the Compressor with varying amounts of friction in the pipe:

2.9 lbs. friction	20.5 lbs. at Compressor.	70.92 efficiency.
5.8 " "	29.4 " " "	64.49 "
8.8 " "	38.2 " " "	60.64 "
11.7 " "	47.0 " " "	57.87 "
14.7 " "	52.8 " " "	55.73 "
17.6 " "	61.7 " " "	53.98 "
20.5 " "	70.5 " " "	52.52 "
23.5 " "	76.4 " " "	51.26 "
26.4 " "	82.3 " " "	50.17 "
29.4 " "	88.2 " " "	49.19 "

So long as the friction of the pipe equals the amounts given, an efficiency greater than the corresponding amounts stated in the table cannot be expected. If we should have a case which corresponded to any of these cited in the table, we could only increase efficiency by reducing the friction.

AN INCREASE IN THE SIZE OF PIPE will reduce friction by reason of the lower velocity of flow required for the same amount of air. But many situations will not admit of large pipes being employed, owing to considerations of economy outside of the question of fuel or prime motor capacity.

AN INCREASE OF PRESSURE will decrease the bulk of air passing the pipe, and in that proportion will decrease its velocity. This will decrease the loss by friction, and, as far as that goes, we have a gain. But we subject ourselves to a new loss, and that is the diminishing efficiencies of increasing pressures. Yet as each cubic foot of air is at a higher pressure and therefore carries more power, we will not need as many cubic feet as before for the same work. It is obvious that, with so many sources of gain or loss, the question of selecting the proper pressure is not to be decided hastily.

AS AN ILLUSTRATION of the combined effect of these different elements we will suppose a very common case.

Compressor 102 revolutions, pressure 52.8 lbs., loss in pipe 14.7 lbs., machine in mine running at 38.2 lbs., efficiency 55.73.

So long as the friction of the pipe amounts to 14.7 lbs., we have seen that 52.8 lbs. is the best pressure and 55.73 the greatest efficiency. We will reduce the friction by reducing the bulk of air passing through the pipe. We reduce the cylinder of the Air Engine so that it requires 47 lbs. pressure to do the same work as before. We find now the friction of pipe drops to 11.7 lbs. The pressure on the Compressor rises to 58.8 lbs., its number of revolutions falls to 100 and the resulting efficiency is 57.22 per cent.

Another change of pressure on Compressor to 64.7 lbs. would decrease its revolutions to 93, friction to 8.8 lbs., and efficiency would rise to 57.94 per cent. Still again increasing pressure to 73.5 lbs. we have only 84 revolutions of Compressor, 5.8 lbs. loss in pipe and efficiency of 57.73 per cent. In this last case the efficiency begins to fall off a little, and higher pressures would now show less efficiency, but, in comparison with the first example, we find we are doing the same work in the mine with a trifle less power and with a decrease of nearly 20 per cent. in the speed of the Compressor.

OTHER COMMON EXAMPLES can be shown where an increase of pressure would result in wonderful increase in efficiency and economy. There are many cases where light pressures and high velocity in the pipe will convey a given power with greater economy than higher air pressures and lower speed of flow through pipe. But these cases arise mostly when the higher air pressures become very much greater than are at present in common use.

THEREFORE IN ESTIMATING THE EFFICIENCY of the complete outfit we find that the pipe and the pressure are very important elements and must be determined with care and skill to secure the most satisfactory results. As the volume and power of air varies with its pressure, the size and consequent cost of Compressor for a certain work would also be affected by the pressure. To plan an outfit for a mine, due regard must be had for cost of fuel or prime motor power, and cost of Compressor, pipes and machinery, as the saving in one is often secured by a sacrifice in the other.

Next to determining the size of pipe, the skillful engineer has need of further care in the proper position of Reservoirs, Branches, Drains and other attachments, as only by the exercise of good judgment in this can satisfactory work be secured.

Reverting now to the subject of reheating, several systems have been suggested and used.

If the only object was to preclude the obstruction of the exhaust ports by the formation of ice due to the moisture of air, it would be obtained by the application to this portion of the engine of some source of heat, such as a lamp, or an injection of steam or of hot water.

This process, however, hardly deserves more than a mere mention, for if such a source of heat is handy, it can be used to far better advantage in heating the air, either in the cylinder or before entering it.

One method consists in injecting into the cylinder a spray of warm water, whose heat is absorbed by the air, while the water is cooled. The annexed table gives the weight of water at 75 degrees, 100 degrees, and 150 degrees Fahr. to be supplied for each pound of air expanding to the atmospheric pressure from 70, 80, 90, and 100 lbs. gauge, so that the final temperature of air will be 32 degrees Fahr., its initial temperature being 60 degrees Fahr.

Gauge Pressure of Air	B. T. U. Required per lb. of Air	Pounds of Water per lb. of Air, the Temperature of Water being		
		75° Fahr.	100° Fahr.	150° Fahr.
Lbs.	(A)	Lbs.	Lbs.	Lbs.
70	59.	1.37	.86	.5
80	62.8	1.46	.92	.53
90	66.2	1.54	.97	.56
100	69.2	1.61	1.02	.6

Another and better method is to inject steam instead of hot water into the cylinder. The advantages of this system are, first, that steam, being in a gaseous state, mixes up with air more readily than water, even finely pulverized, and besides, the condensation of this steam gives up its latent heat, which increases considerably the heating of air.

A comparison of this process with the previous one can readily be made. Assuming that a spray of water at 212 degrees Fahr. is injected into the cylinder, each pound of this water will give up 180 B. T. U. before it is cooled to 32 degrees Fahr.

But, taking steam at atmospheric pressure, i. e., also at 212 degrees Fahr., 1 lb. of steam, in the process of liquefaction, will abandon 966 B. T. U., its latent heat of vaporization, and besides 180 B. T. U. as above, making a total of 1146 B. T. U.

The following table gives the weight of steam at 212 degrees Fahr. required for each pound of air to prevent its temperature from falling below 32 degrees Fahr. at complete expansion.

Gauge Pressure of Air Lbs.	B. T. U. Required for each lb. of Air	Lbs. of Steam at 212 Degrees per lb. of Air
70	59.0	.051
80	62.8	.055
90	66.2	.059
100	69.2	.0604

It is evident that quite similar calculations could be made to maintain the exhaust temperature at any given point. Besides, the use of steam keeps the walls of the cylinder wet, and while water alone is a poor lubricant between metallic surfaces, it facilitates the action of the regular lubricants, and is also favorable to the tightness of the piston packing.

It will readily be seen that both these methods completely preclude the formation of ice in the exhaust ports; their good effect is still more pronounced if the cylinder is provided with a jacket, into which hot air is circulated.

Air can also be reheated before being admitted into the cylinder. Various designs of heaters are used for this purpose, the air generally passing through a system of pipes heated by an interior furnace, a flue being provided for the passage of the hot gases on the outside of the pipes before they reach the chimney. And as air, on account of its bad conductivity, does not easily take up heat from the metallic sides of the pipes, it is expedient to inject in the pipes a small quantity of water, which absorbs the heat more readily and penetrates with the hot air into the cylinder.

Another method of heating is to place a lamp or gas jet within the air pipe. The use of coal or wood is not advisable in this case, as grit and cinders would be carried by the current of air into the motor.

Reheating by the electric current is still in the experimental state.

When the motor is a compound machine, the air should be again reheated after it has done work in the H. P. cylinder, and before it is admitted to the L. P. cylinder.

If the heating is done by passing the air through heated pipes, the fuel consumption will be very small, as practice shows that 1 lb. of coal gives the air from 8,000 to 10,000 B. T. U. in a properly designed heater.

To utilize the full benefit of reheating and of air expansion in compound engines, an early cut-off is very desirable. This can be accomplished by reheating to 350 degrees before the air enters each cylinder.

Table showing temperature of dry air at the end of its compression to different gauge pressure in adiabatic compression, i. e., supposing that no portion of the heat developing is lost in the course of compression.

Absolute Pressure. (Lbs. per sq. in.)	Gauge Pressure. (Lbs. per sq. in.)	Fah. temperature, in degrees, at end of compression.
14.7	0	60
16.17	1.47	74.6
18.37	3.67	94.8
22.05	7.35	124.9
25.81	11.11	151.6
29.4	14.7	175.8
36.7	22	218.3
44.1	29.4	255.1
51.4	36.7	287.8
58.8	44.1	317.4
73.5	58.8	369.4
88.2	73.5	414.5
102.9	88.2	454.5
117.6	102.9	490.6
132.3	117.6	523.7
147	132.3	554
220.5	205.8	681
294	279.3	781
367.5	352.8	864

The different styles of jacketing and spray injection will show from 75 to 90 per cent of isothermal efficiency.

TRANSMISSION OF POWER BY COMPRESSED AIR

The advantage of transmitting power by compressed air is daily gaining in importance, and we take this opportunity of placing before the public an example of plants of this kind.

200-horse power, delivered by wheel and transmitted 2 miles through 7-inch pipe, the pressure at power station to be 80 pounds, the line loss will be 3 pounds, and the air delivered will be 1200 cubic feet (free air) at a pressure of 77 pounds.

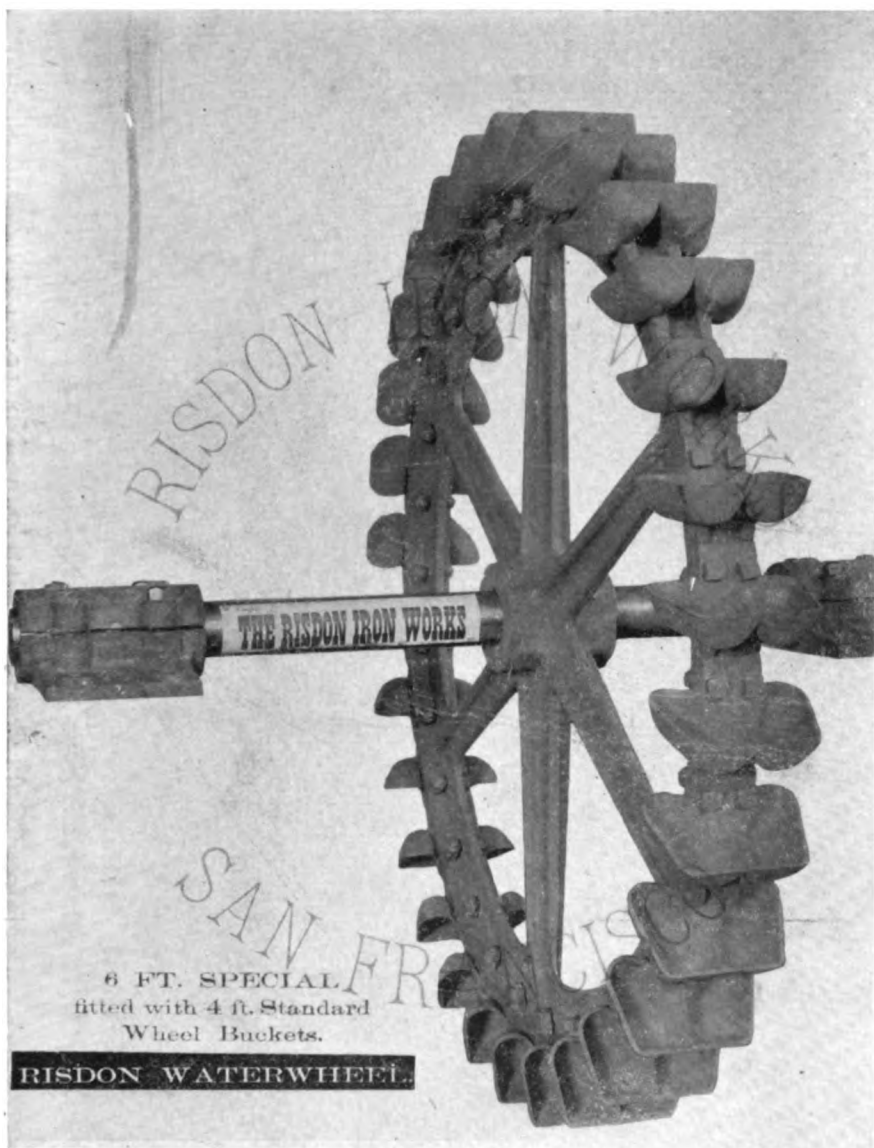
The available work performed by this air, if used cold, will be 55 per cent, and if reheated to 300 degrees, will be 80 per cent, and if reheated to 350 degrees, will be 85 per cent.

The fuel required to do this reheating will be about 1 cord per 24 hours.

The above air will run a 40-stamp combination mill; also 2 rockbreakers and a hoisting engine, capable of hoisting 200 tons of ore per day; also the necessary drills and blower engine used in ventilation.

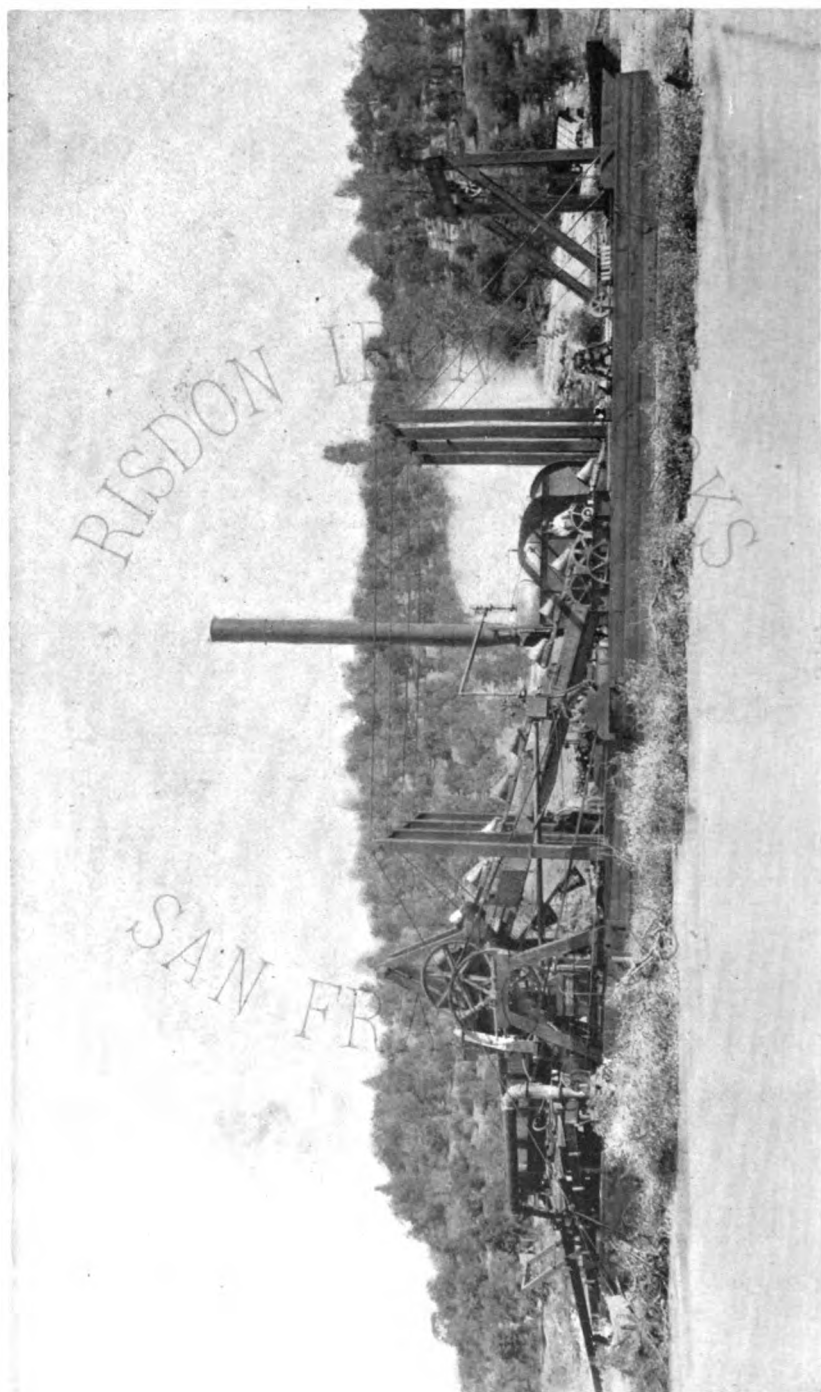
We assume in the above that 1 lb. wood will yield 5000 B. T. U.

We illustrate a large compressor of this kind on pages 31, 33 and 35.



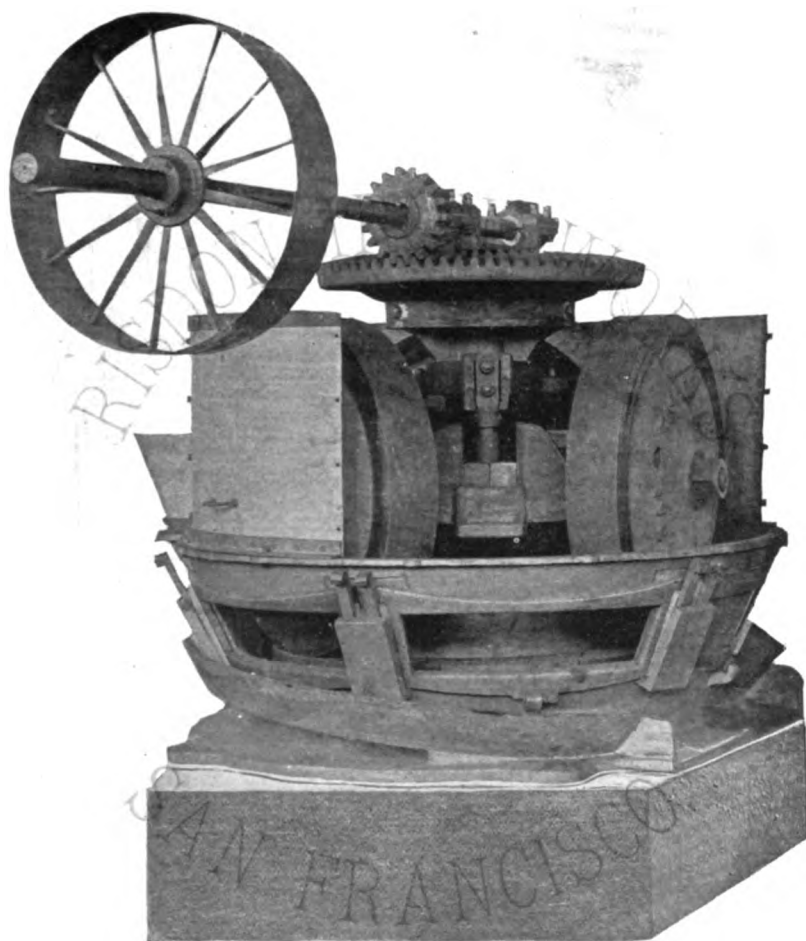
This wheel develops 300-horse power running 280 revolutions per minute, under a hydrostatic head of 500 feet.

(Page from Water Wheel Catalogue, No. 4)



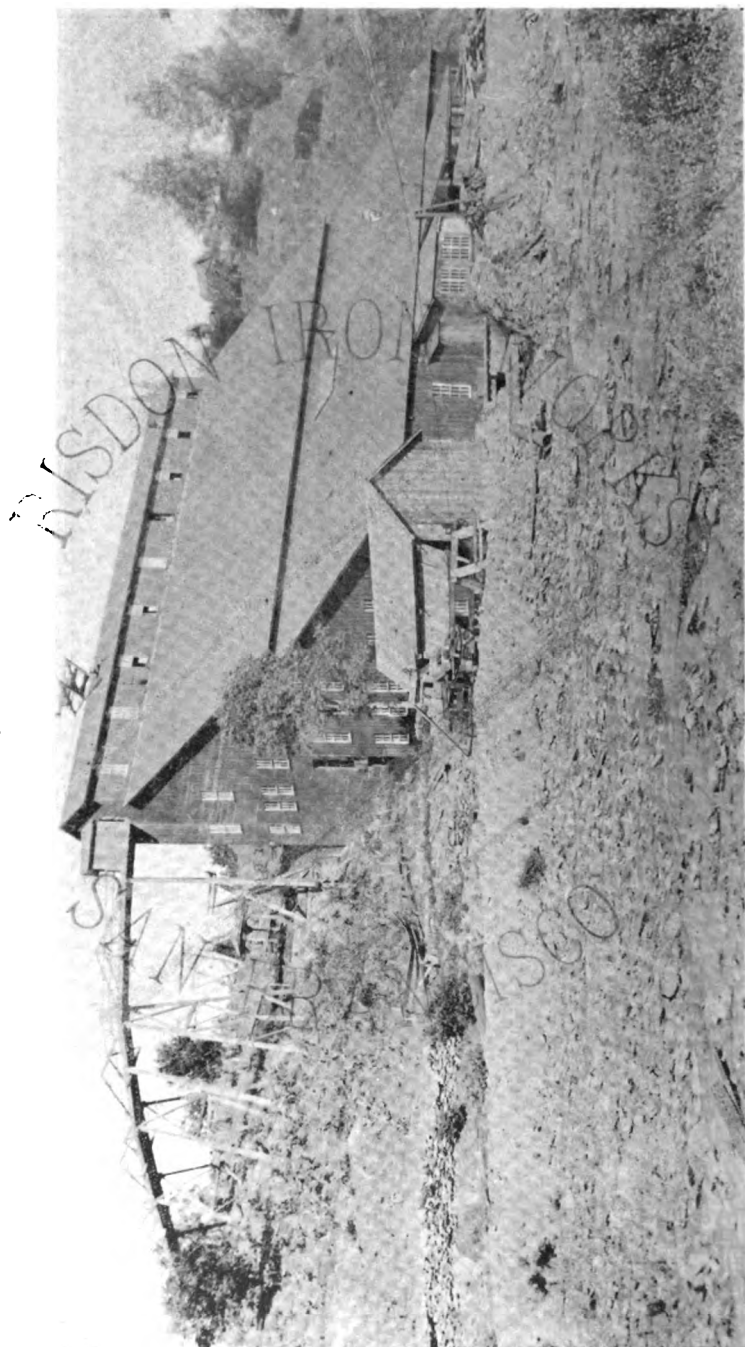
Page from Gold Dredging Catalogue No. 15

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Bryan Roller Quartz Mill
ADAPTED TO THE
Milling and Reduction of Gold and Silver Ores

(Page from Bryan Mill Catalogue, No. 8)

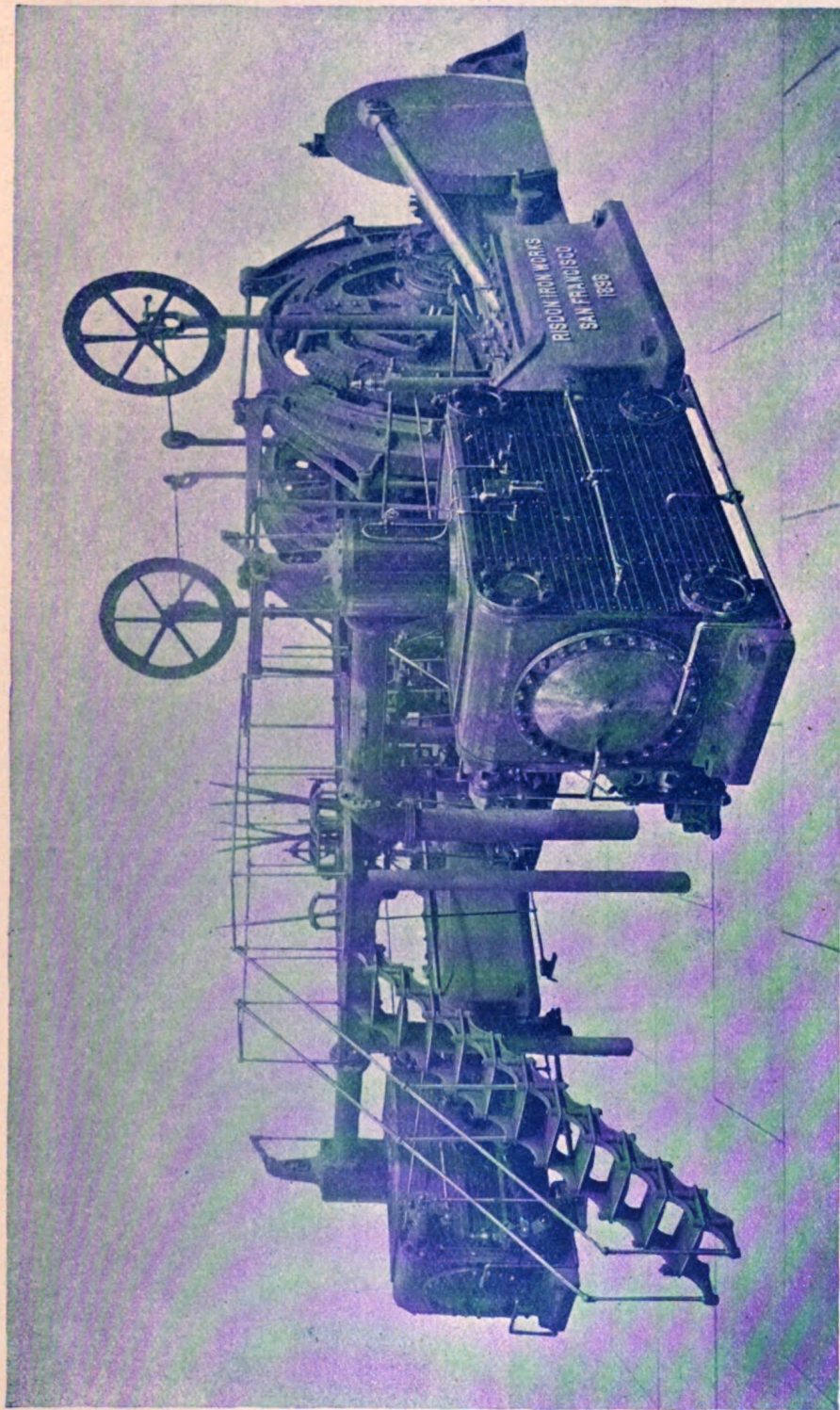


60-Stamp Concentrating Gold Mill, "Water Power," 900 lb. Stamps, crushing 280 tons (4,000 tons per stamp) per day, through 40 mesh screen.
All Machinery built by Risdon Iron Works. (Page from Milling Catalogue No. 12.)

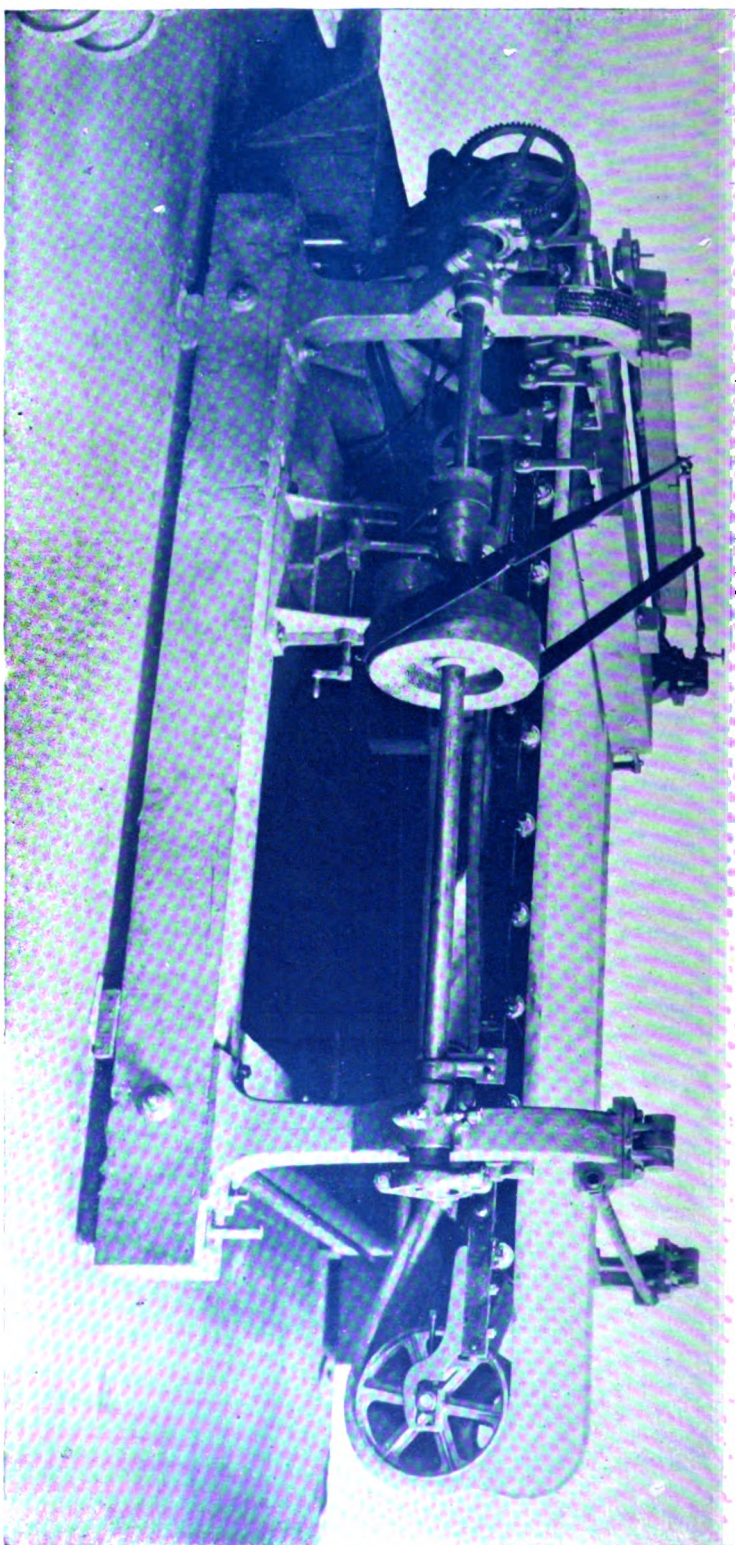
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3000 HORSE POWER HOISTING ENGINE

Page from Hoisting Catalogue No. 3



Direct Acting Hoisting Engine, to start load 40,000 lbs. and hoist same at an average speed of 3000 feet per minute. Capacity, 3500 feet Rope.



Johnstone Concentrator, Risdon Iron Works, Sole Manufacturers.

(Page from Johnstone Concentrator Catalogue No. 14)